This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Digitized by Google

Chem 7108.95.5

Harvard College Library

BOUGHT WITH INCOME

FROM THE BEQUEST OF

HENRY LILLIE PIERCE

OF BOSTON

Under a vote of the President and Fellows
October 24, 1898

March 21, 1902.

SCIENCE CENTER LIBRARY

Digitized by Google

Digitized by Google

Digitized by Google

GROVES AND THORP'S

CHEMICAL TECHNOLOGY

OR

CHEMISTRY

APPLIED TO ARTS AND MANUFACTURES

VOL. III.

GAS LIGHTING

Digitized by Google

Digitized by Google

CHEMICAL TECHNOLOGY

OR

CHEMISTRY IN ITS APPLICATIONS TO ARTS AND MANUFACTURES

EDITED BY

CHARLES EDWARD GROVES, F.R.S.

LECTURER IN CHEMISTRY, GUY'S HOSPITAL

AND

WILLIAM THORP B.Sc.

WITH WHICH IS INCORPORATED

RICHARDSON AND WATTS' CHEMICAL TECHNOLOGY

VOL. III.

GAS LIGHTING

BY

CHARLES HUNT

MANAGER OF THE BIRMINGHAM CORPORATION GASWORKS

ILLUSTRATED

PHILADELPHIA

P. BLAKISTON'S SON & CO.

1012 WALNUT STREET

1900

Digitized by Google

CHEM7108.95.5

Pierce fund

Digitized by Google

PREFACE.

THIS, the third volume of Chemical Technology, gives a history of the manufacture of gas and its application to the purposes of illumination. As distinguished from oil, wax, and fats, which have been employed from the earliest times as sources of artificial light, the use of gas for this object is not yet a century old, at all events in this country, and although electric lighting is more convenient and cleaner than gas, the introduction of the Welsbach and other incandescent burners, aided by the relatively low cost of gas, will no doubt enable it to maintain the important place it occupies as an illuminating agent.

The first portion of the work is devoted to the history of gas lighting, and statistics are given illustrating the very large amount of capital employed in this important manufacture, and its vast extent; numerous analyses of various gas-coals being also quoted.

The process of carbonisation of coal is then considered, showing the different products formed, and the effect on carbonisation produced by variation in temperature. This naturally leads to the methods employed, and there are full descriptions not only of the retorts and the various methods of closing them, but also of the furnaces in which they are heated. The latter are considered in historical order, ending with the most recent recuperative or regenerative furnaces and the machinery now often employed in large gas works for mechanical charging and drawing the retorts, an operation which was formerly always done entirely by hand. The use of machinery has the advantage not only of dispensing with a large amount of manual labour, but also of distributing the coal very evenly in the retorts, and consequently of providing for a more equable and thorough carbonisation.

The methods proposed for the removal of the tar and other subsidiary products are next discussed, and the kinds of condensors and tar-extractors in general use are fully described. A short chapter follows on the exhausters used for diminishing the pressure in the retorts, and then the various washers and scrubbers employed for removing the ammonia from the cooled gas are illustrated and their construction and mode of action explained, stress being laid on the very important part played by the ammoniacal liquor, in the more recent purifying machines, in removing

Digitized by Google

not only a large proportion of the sulphuretted hydrogen but also of the carbonic acid, thus diminishing the cost of the subsequent purification.

In order to judge of the effect thus produced, it is necessary to know the amount of "volatile ammonia," of carbonic acid, and of sulphuretted hydrogen in the ammoniacal liquor used for this purpose, and with this object simple analytical processes for determining these factors are given.

The next chapter treats of the ammoniacal liquor. Full details of an analytical method for determining its value are given, and also descriptions of the more important apparatus devised, either for obtaining "*liquor ammoniæ*" from it, or for converting it into sulphate of ammonia, enormous quantities of which are used for agricultural purposes.

Amongst the "residuals," the cyanogen compounds produced in the carbonisation of coal have recently assumed considerable importance, since the introduction of the cyanide process for treating the tailings from the stamped quartz of the African gold mines. Cyanogen exists in coal gas either as such or as hydrogen cyanide, especially when the coal is carbonised at a high temperature, much of it being removed from the gas by the oxide of iron used in purifying. It may also be extracted from the gas by means of freshly precipitated ferrous carbonate. In either case, the cyanogen is obtained as ferrocyanide. A very large proportion of the total cyanogen, however, is found in the ammoniacal liquor in the form of thiocyanate (sulphocyanide) of ammonium.

After the ammonia has been removed, the gas has to be purified from the sulphuretted hydrogen and carbonic acid it still contains. The section on purifiers treats of the methods employed for this purpose; including a discussion of wet and dry lime purifiers; oxide of iron purifiers; the revivification of the oxide, and the use of oxygen for that purpose as proposed by Valon. A full description is also given of the Claus purifying process as applied experimentally on a large scale at the Windsor Street Gasworks of the Birmingham Corporation. This is followed by detailed descriptions of processes for analysing the purifying materials, and also of the gas both before and after it has undergone purification.

The storage of the gas and its distribution is then considered, and the various kinds of gas-holders described, including the most recent developments of multiple lift gas-holders; Gad and Mason's spiral guides; Pease's wire rope guides, &c.; the station and district governors; and automatic pressure changers for regulating, and the pressure indicators for measuring the pressure.

Gas meters have passed through numerous changes since Clegg's first meter was patented in 1815. Typical examples of the various kinds of wet meters are described, and then dry meters, which have now almost entirely superseded the wet meters for domestic purposes, owing to the inconvenience attending the use of the latter from the water being liable to be frozen if the meter is exposed, and from the condensation of the

Digitized by Google

water vapour in the domestic service pipes. These defects are entirely obviated in the dry meters.

Processes for enriching ordinary gas by the use of volatile hydrocarbons are mentioned, and the Dinsmore process for enrichment by means of coal-tar is fully described. There is a short notice of oil gas, and this is followed by carburetted water-gas, the manufacture of which is fully treated. The advantages of this system are considerable from a gas-maker's point of view, especially if employed to supplement the make of ordinary coal-gas. There is great economy of space, the process is cleanly and free from nuisance, and the plant can be rapidly set working to supply gas when there is a sudden demand, as in foggy weather; moreover, as surplus coke is used up in the manufacture, a better price is obtained for that which goes into the market. A further very important consideration is that owing to the very small number of men required to work the plant, it is of great service when the ordinary works are disturbed or stopped by strikes or other labour troubles. There is, however, one great objection to its use, and that is the very large proportion of carbonic oxide (30 per cent. or more) it contains as compared with ordinary coal-gas, which usually contains less than 6 per cent.; for carbonic oxide is not only a deadly poison, but it is a cumulative poison, so that a slight escape of gas in a bedroom which might be of little moment if it were coal-gas might be fatal if the gas were mixed with any considerable proportion of water-gas.

The last section of the work is devoted to gas-burners, attention being drawn to the economic importance of the burner being suited to the pressure at which the gas it has to burn is supplied, and the means by which this can be attained. The more important flat flame burners are fully described, and then the regenerative burners. In conclusion, a full account of the incandescent burners is given; these have already effected a revolution in gas-lighting, and from the brilliancy of the light, and the economy arising from the comparatively small amount of gas they consume, have enabled it to compete with electricity as an illuminating agent, and no doubt these burners are capable of still further improvement.

In conclusion, we desire to acknowledge our indebtedness to Mr. H. Kühne, Messrs. W. Parkinson & Co., The Proprietors of the *Electrical Review*, the *Journal of Gas Lighting*, the Denayrouze Light Syndicate, the Incandescent Light Co., and others, for their courteous permission to use valuable illustrations.

Digitized by Google

Digitized by Google

CONTENTS.

	PAGE
Introduction	1
Early History of Gas Manufacture	3
Gas Manufacture	7
Gas Coal	9
Analyses of Cannel Coals	9, 14
Analyses of Gas Coals	11
Composition of Coal	18
Carbonisation of Coal	18
Products of Carbonisation	18
Effect of Temperature on Carbonisation	20
Gas Retorts	24
Iron Retorts	24
Closing Retorts	24
Clay Retorts	26
Built up Retorts	27
The Furnace, Oven, or Bench	29
Setting of Retorts	29
Croll's Furnace	31
Lowe's Furnace	34
Schilling Regenerative Furnace	35
Liegel Regenerative Furnace	38
Klönne Furnace	41
Hunt's Modification of Klönne's Furnace	41
Siemens' Recuperative Furnace	43
Valon's Regenerative Furnace	45
Bunte's Gas Analysis Apparatus	46
Stoking Machinery	48
Foulis and Woodward's System	48
Foulis Hydraulic Drawing Machine	49
Arrol-Foulis Hydraulic Charging Machine	49
West's Charging and Drawing Apparatus	52

Digitized by Google

PAGE

Stoking Machinery (*continued*)
Ross Charging Machine 52
Improved Ross Charging Machine 52
Ross Drawing Machine 53
Elliott's Continuous Carbonisation 57
Coze's System of Inclined Retorts 60

Hydraulic Main 60
Dillaman's Tar Receiver 63
Chandler and Stevenson's Self-acting Dip-pipe 63

Retort House 64

Condensation 64
Atmospheric Condenser 66
Graham's Horizontal Condenser 66
Battery Condenser 68
Wright's Condenser 68
Morris and Cutler's Perfect Condenser 70
Influence of Condensation on the Illuminating Power 70

Tar Extractors 75
Pelouze and Audouin's Tar Extractor 75
Livesey Washer 76

Exhausters 79
Grafton's Exhauster 81
Beale's Exhauster 81
Waller's Exhauster 81
Körting's Steam Jet Exhauster 83

Washers and Scrubbers 83
Croll's Washer 84
Marriott's Process 85
Walker's Washer 87
Livesey's Scrubber 90
Hunt's Gas Washer 90
Cleland's Scrubber 93
Paddon's Scrubber-Washer 93
Kirkham Scrubber-Washer 94
Walker's Purifying Machine 94
Estimation of Carbonic Acid and Sulphuretted Hydrogen in Ammoniacal Liquor 97

Ammoniacal Liquor 95
Valuation of Ammoniacal Liquor 98
Manufacture of Sulphate of Ammonia from Ammoniacal Liquor . . 99
Grüneberg and Simon's Sulphate of Ammonia Apparatus . . . 101
Ammonia Still 101, 102
Feldmann's Sulphate of Ammonia Apparatus 103
Wilton's Patent Automatic Discharger 103
Cost of Manufacture of Sulphate of Ammonia 106
Cyanogen Compounds as Residuals 107
Estimation of Hydrocyanic Acid in Coal Gas 108

Digitized by Google

PAGE

Purifiers 110
Wet Lime Purifier 110
Dry Lime Purifier 111
Dry-faced Centre Valve for Purifiers 111
Single Slide Valve for Lime Purifiers 111
Cutler's Hydraulic Valve 113
Weck's Centre Valve 114
Water lutes of Purifiers. 117
Arrangement of Purifier House 119

Purification 120
Partial Purification, Removal of Sulphuretted Hydrogen only . . 120
Partial Purification, Removal of Sulphuretted Hydrogen and Carbonic Acid 121
Complete Purification 122
Use of Oxygen in Purification 126
Purification in Closed Vessels 128
Claus Purifying Process 129
Holgate's Ammoniacal Liquor Purifier 132

Purifying Materials 135
Oxide of Iron 135
Spent Oxide of Iron 135
Lime 136
Spent Lime 136

Analysis of Gas 137
Analysis of Unpurified Gas 137
Wright's Method 137
Orsat-Muencke Gas Analysis Apparatus 138
Sheard's Carbonic Acid Apparatus 141
Folkard's Method of Estimating Carbonic Acid 142
Harcourt's Colour Test for Carbon Bisulphide 142
Analysis of Purified Gas 144
Testing for Sulphuretted Hydrogen 145
Testing for Ammonia 145
Testing for Sulphur Compounds other than Sulphuretted Hydrogen 146

Measurement and Storage of Gas 148
Station Meter 148
Gasholders 150
Construction of Gasholder Tanks 151
Capacity of Gasholders 154
Telescopic Gasholders 154
Flat Cup and Grip 159
Piggott's Cup and Grip 156
Trussed Gasholders 156
Guide-framing for Gasholders 159
Cutler's Guide-framing 161
Gadd and Mason's Spiral Guides 162
Pease's Wire Rope Guides 164

Digitized by Google

PAGE

Governors and Indicators 168
Governor with Air Vessel 168
Hunt's Equilibrium Governor 170
Parkinson's Double-Cone Equilibrium Governor 170
Braddock's Station Governor 170
Cowan's Automatic Pressure Changer 174
Price's Automatic Pressure Changer 175
Crosley's Indicator 175
Wright's Indicator 176
See also District Governors 182–183

Distributing Mains and Pipes 177
Junction of Cast-iron Pipes 178
King's Turned and Bored Joint 178
Friction in Mains 179
District Governors 182
Foulis District Governor 182
Jones' Differential Governor 183
Parkinson's District Governor 183
Service Pipes 183
Stoppages in Service Pipes 184
Naphthalene 184

Gas Meters 187
Wet Meters 187–194
Clegg's Meter 187
Crosley's Meter 188
Crosley's Open-float Meter 189
Esson's Meter 190
Sanders and Donovan's Compensating Meter 190
Clegg's Hydraulic Meter 190
Warner and Cowan's Meter 190
Mead's Meter 193
Hunt's Compensating Meter 193
Official Inspection of Gas Meters 193
Pinchbeck's Meter 194
Dry Meters 194
Clegg's Dry Meter 195
Defries' Dry Meter 196
Croll and Richard's Meter 196
Parkinson's Pressure Raiser 198
Prepayment Meters 198

Enrichment Processes, Oil Gas, Carburetted Water Gas . 201
Paraffins 201
Vapour Tension of Water, Benzene, &c. 204
Distillation and "Cracking" 207
Enrichment with Hydrocarbon Vapours 208
Maxim and Clark's Apparatus for Enrichment 208
Enriching Values of Petroleum spirit, Oil-Gas spirit, and Benzene . 208

Digitized by Google

PAGE

Enrichment Processes, Oil Gas, Carburetted Water Gas (*continued*)

Dinsmore Enrichment Process with Coal Tar 212
Oil Gas 219-229
Pintsch's Oil Gas Producer 220
Mansfield's Oil Gas Producer 221
Patterson's Oil Gas Retort 221
Young and Bell's Oil Gas Apparatus 223
Carburetted Water Gas 226
Early Processes 227
Sander's Water Gas Apparatus 227
Edgerton's Water Gas Apparatus 227
Tessie du Motay Water Gas Apparatus 229
Wilkinson Water Gas Apparatus 229
Lowe's Apparatus 228, 232
Granger Modification of Lowe's Apparatus 232
Springer Water Gas Apparatus 232
Improved Lowe Apparatus 232
Merrifield-Westcott-Pearson Water Gas Apparatus 236
Composition of Carburetted Water Gas 241
Calorific Power of Carburetted Water Gas 241
Advantages of Carburetted Water Gas 242
Acetylene 244
Manufacture of Calcium Carbide 246
Home Office Regulations for Calcium Carbide 248

Combustion 249
Determination of Calorific Power of Combustibles 249
Hartley's Calorimeter 250
Junker's Calorimeter 251
Calorific Value of the Constituents of Coal Gas 255, 256

Gas-Burners 257-307
Argand Burners 258
Cockspur Burner 258
Audouin and Bérard's Experiments in Gas Burners 261
Sugg's London Argand 261
Flat Flame Burners 262
Batswing Burner 262
Fishtail Burner 262
Importance of Low Gas Pressure in Using Flat Flame Burners . . . 263
Wadsworth's Hollow-top Burner 263
Sugg's Hollow-top Batswing Burner 263
Bönner's Flat Flame Burners 264
Bray's "Regulator" and "Special" Flat Flame Burners 264
Comparative Lighting Power of Bray's Flat-flamed Burners . . . 265, 266
Bray's High Power Burner 267
Sugg's Table Top Burner 267
Photometric Measurement of Street Lamps 267

Digitized by Google

PAGE

Gas-Burners (*continued*)

Bray's Street Lantern 270
Sugg's Street Lantern 270
Governor Burners 270–276
Giroud's Rheometer 272
Sugg's Christiania Burner 272
Borradaile's Burner 272
Peeble's Needle Governor Burner 274
Parkinson's Automatic Gas Burner 274
Orme's Regulator Burner 274
Gas Globes 276
Sugg's Christiania Globe 276
Gardner's Globe 276
Ker and Green's Chimney and Globe 278
The Cromartie Lamp 280
Regenerator Burners 283
Leslie's Argand Burner 283
Bowditch's Regenerative Burner 284
Siemens' Regenerative Burner 284
Siemens' Flat Flame Regenerative Burner 284
Clark's Burner 287
Grimston's Burner 287
Sugg's Cromartie Burner 289
Wenham Burner 289
Schulke's Lamp 290
Sun Burners 291
Strode's Sunlight 293
Hunt's Sunlight 293
Incandescent Burners 294–307
Lewis' Burners 294
Clamond Incandescent Lamp 295
Improved Clamond Lamp 295
Welsbach Incandescent Lamp 296
Illuminating Power of Welsbach Lamp . . . . 298, 304 *et seq.*
Improved Welsbach Lamp 299
Denayrouze Burner 301
Bandsept Burner 302
The Kern Burner 302
Sunlight Company's Mantle 304

INDEX 309

Digitized by Google

ILLUSTRATIONS.

	FIG.	PAGE
APPARATUS FOR ANALYSIS OF GAS :—		
Ammonia cylinder	124	145
Bunte's gas analysis apparatus	40	47
Harcourt's carbon bisulphide apparatus	123	142
Orsat-Muencke apparatus	120	138
Sheard's carbonic acid apparatus	121, 122	141
Sulphur testing apparatus	125	146
CALORIMETERS :—		
Hartley's calorimeter	209	251
Junker's calorimeter	210, 211	252, 253
CHIMNEYS :—		
Chimney, Argand	248	279
Chimney, Ker and Green's globe and	243-247	278
CONDENSERS AND TAR EXTRACTORS :—		
Atmospheric condenser	56	67
Battery condenser	57–60	68, 69, 71
Graham's horizontal flat-screw condenser	55	66
Livesey washer	68, 69	77, 78
Morris and Cutler's Perfect condenser	62-65	74
Pelouze and Audouin's tar extractor	66, 67	76, 77
Wright's condenser	61	72
CURVES :—		
Curve of hourly midwinter output	128	150
„ illustrating effect of dried air supply to burners	250	282
„ illustrating illuminating power of gas with varying air supply	192	210
„ giving illuminating power of Incandescent Gas Light Co.'s burners	290	304
„ illustrating "life" of a mantle, candle-power and hours	291	305
„ illustrating percentage of initial candle-power in mantles	292	305
Curves illustrating naphthalene stoppages, and temperature of gas at outlet	171	186
DISTRIBUTING MAINS, AND PIPES :—		
Cast-iron main joint	164	178
Curves illustrating naphthalene stoppages and temperature of gas at outlet	171	186
King's turned and bored joint	165	179
Syphon for mains	166	179
ENRICHMENT PROCESSES :—		
Dinsmore enriching apparatus	193, 194	213
Maxim and Clark's enriching apparatus	191	209
EXHAUSTERS :—		
Beale's exhauster	70, 73	79, 81
Grafton's exhauster	71, 72	80
Körting's steam jet exhauster	80	83
Waller's three-blade exhauster	74-78	82
Waller's four-blade exhauster	79	82

Digitized by Google

	FIG.	PAGE
FURNACE, OVEN, OR BENCH :—		
American setting of retorts	22	31
Bench of three retorts	20	30
Bench of five retorts	21	31
Bench of seven retorts	19	30
Coze's inclined retorts	50	61
Croll's Furnace	23-25	32, 33, 34
Elliott's continuous carbonisation	49	59
Hunt's modification of Klönne's system	35	42
Klönne's system	34	40
Liegel's regenerative furnace	32, 33	29
Lowe's Furnace	26	35
Retort House, Birmingham	54	65
Schilling's regenerative furnace	27-31	36, 37, 38
Section of clay oven and setting	8, 9	26
Setting of retorts (section and elevation)	17, 18	29 30
Siemens' recuperative furnace	36, 37	44
Valon's regenerative furnace	38, 39	45
GAS-BURNERS :—		
Argand burner, Leslie's Argand	251	283
Argand burner, Sugg's London	213	261
Batswing burner	214	262
„ burner, hollow-top	215	263
„ burner, Brönners	217	264
„ burner, Bray's high-power	221	267
„ burner, Bray's special	220	265
„ burner, Sugg's steatite hollow-top	267	264
„ burner, Sugg's table-top	222	267
Bray's fishtail or union burner	218	265
Bray's special slit-union	219	265
Cockspur burner	212	258
Governor burner, Borradaile's	229	273
„ „ Giroud's Rheometer	227	272
„ „ Orme's	236, 237, 238, 239	275, 276
„ „ Parkinson's automatic	232, 233, 234, 235	274, 275
„ „ Peeble's needle	230	273
„ „ Peeble's modified	231	273
„ „ Sugg's Christiania	228	272
Regenerative burner, Bowditch's	252	284
„ „ Clark's	256	287
„ „ Grimston's	257, 258	288
„ „ Schulke's	262	291
„ „ Siemens'	253, 254	285
„ „ Siemens' flat-flame	255	286
„ „ Sugg's Cromartie	259	287
„ „ Wenham	260, 261	290
Incandescent burner, Bandsept	287	301
„ „ Clamond	269, 270, 271	295, 296
„ „ Denayrouze	285, 286	301
„ „ Kern	288, 289	303
„ „ Lewis	267, 268	296
„ „ Welsbach	272-284	297-300
GAS-METERS :—		
Clegg's meter	172	187
Clegg's dry meter	184, 185	195
Croll and Richard's dry meter	187	197
Crosley's meter	173-175	188
Crosley's open-float meter	176	189
Defries' dry meter	186	197
Hunt's compensating meter	181	193
Parkinson's prepayment meter	189, 190	200
Pinchbeck's meter	182, 183	194
Sanders and Donovan's compensating meter	177, 178	191
Warner and Cowan's meter	179, 180	192
Works meter, large	127	149
Works meter, small	126	149
GOVERNORS AND PRESSURE CHANGERS, AND INDICATORS :—		
Governors	151-154	186, 169
Braddock's station governor	157, 158	172
Foulis' District governor	167	181

Digitized by Google

	FIG.	PAGE
GOVERNORS AND PRESSURE CHANGERS, AND INDICATORS (*continued*)		
Hunt's equilibrium governor	155	170
Jones' Differential governor	169	182
Parkinson's double cone governor	156	171
Parkinson's District governor	170	183
Peeble's District governor	168	181
Parkinson's pressure raiser	188	199
Cowan's automatic pressure changer	159	173
Price's automatic pressure changer	160, 161	174, 175
Crosley's indicator	162	176
Wright's indicator	163	177
HYDRAULIC MAIN:—		
Chandler and Stevenson's dip-pipe	53	64
Hydraulic main	51, 52	61
LANTERNS, LAMPS, AND GLOBES:—		
Lantern, Bray's	226	271
„ Schulke's	203	296
Street Lantern, Sugg's	225	270
Lamp, Cromartie, and Ventilating Shaft	249, 259	280, 289
Lamps, Schulke's	262	291
„ Wenham's	260, 261	290
„ incandescent, Clamond	269, 270, 271	295, 296
„ „ Denayrouze	285, 286	301
Sunlight, Welsbach	274	298
„ Hunt's	265, 266	293
„ Strode's	264	292
Globe, Gardner's	241, 242	279
„ Ker and Green's Chimney and	243-247	278
„ Sugg's Christiania	240	277
OIL GAS, CARBURETTED WATER GAS:—		
Mansfield's oil gas producer	196	221
Patterson's oil gas retort	197	222
Pintsch's oil gas retort	195	220
Young and Bell's oil gas apparatus	198	224
Edgerton water gas apparatus	199, 200	228
Lowe water gas apparatus	203, 204, 206, 207	232, 233, 235, 237
Merrifield-Westcott-Pearson water gas apparatus	208	238
Springer water gas apparatus	205	234
Tessie du Motay water gas apparatus	201	229
Wilkinson water gas apparatus	202	230
PHOTOMETRIC MEASUREMENT OF STREET LAMPS	223	268
Sighting box of photometer	224	268
PURIFIERS AND PURIFICATION:—		
Claus purifying process	116-118	130, 131
Grid for dry lime purifier	102	111
Holgate's ammoniacal liquor purifier	119	133
Oxygen furnace	114, 115	126, 127
Plan for set of four purifiers	104	113
Purifier with cover	103	112
Section of Purifier House, Nine Elms	113	119
Wet lime purifier	101	110
Valve, Cutler's hydraulic	107, 108	115
„ dry-faced centre	105	113
„ single slide	106	114
„ Weck's centre	109-112	116, 117
RETORTS:—		
Built-up clay retorts	11-16	28
Coze's inclined retorts	50	61
D-shaped clay retort	10	27
Holman's Fastening	6, 7	25
Lid of retort	4, 5	25
Retorts	1-3	24

Digitized by Google

	FIG.	PAGE
STOKING MACHINERY:—		
Arrol-Foulis hydraulic charging machine	43	51
Coze's inclined retort	50	61
Elliott's continuous carbonisation	49	59
Foulis hydraulic drawing machine	41	50
Ross charging machines	46, 47	56, 57
Ross drawing machine	48	58
West's drawing apparatus	43	53
West's charging machine	45	55
West's machinery, general view	44	54
STORAGE OF GAS:—		
Cup and grip for telescope gasholder	133, 134	155
Cutler's guide framing	143, 144	161
Diagram of hourly midwinter output	128	150
Gadd and Mason's spiral guides	147	163
Gasholder	129	151
Gasholder tank	130, 131	152, 153
Livesey's radial and tangential rollers	138	158
Pease's wire rope guides	148–150	164, 166, 167
Section of gasholder	132	155
Standards for guide framing	139–142	159, 161
Telescope gasholder at Rotherhithe	145	162
Trussed gasholder	135, 136	157
Untrussed gasholder	137	157
Webber's gasholder	146	163
TREATMENT OF AMMONIACAL LIQUOR:—		
Apparatus for valuation of ammoniacal liquor	94	99
Apparatus for obtaining ammonia from ammoniacal liquor	96 98	102, 103
Feldmann's sulphate of ammonia apparatus	99	104
Grüneberg and Simons' sulphate of ammonia apparatus	95	101
Sulphate of ammonia apparatus, with Wilton's automatic discharger	100	105
WASHERS AND SCRUBBERS:—		
Cleland's scrubber	89, 90	92, 93
Croll's washer	81	84
Hunt's washer	87, 88	91, 92
Kirkham-Hulett-Chandler scrubber-washer	91, 92	94, 95
Livesey's washer	68, 69	77, 78
Livesey's scrubber	85, 86	88, 89
Walker's purifying machine	93	96
Walker's washer	82, 84	86, 87

PLATES.

PLATE I. Typical plan of gasworks . . . . . p. 8

PLATE II. Wet lime purifier . . . . . p. 86

Digitized by Google

CHEMICAL TECHNOLOGY.

GAS LIGHTING.

INTRODUCTION.

It appears difficult to realise that coal gas, which is to us so familiar, should have a history of only some eighty-five years, so far as its practical application as a means of lighting is concerned. It is true it was known early in the eighteenth century that an inflammable gas could be obtained by heating coal, and more direct attempts were made about the year 1802 to apply it as a source of light, but the Gas Light and Coke Company did not obtain incorporation until 1810, and this appears to be the first attempt to supply gas to the public in a systematic manner for the purpose of lighting.

All earlier methods of illumination had the characteristic that the light was produced as required from the material consumed, the resinous piece of wood, the fat of the candle, or the oil of the lamp, was in close proximity to the flame giving light. In other words, the gaseous products which furnished the light were consumed on the spot as fast as made. In the more modern methods of lighting by coal gas or electricity, however, this is not the case; gas may be made from the coal, or the heat developed by the combustion of the latter may be converted into electricity, and the gas or the electric current can be transmitted to any desired spot and the light produced there at a distance from the gasworks or the dynamo. These two systems are in the main restricted to populous places, for in both cases comparatively large and costly plant is necessary, and a certain amount of skilled attention is required to supervise the manufacture or machinery, although the subsequent use and management of the light may be exceedingly simple and inexpensive. Indeed, it is absolutely necessary to the popular use of any such system of lighting, in its earlier stages at all events, that the means employed for the actual production of the light should be of this simple and inexpensive character. If special and skilled attendance is required, it may be possible to apply them in a few instances in very large establishments or public buildings, but the general use for domestic purposes cannot prevail until all the necessary appliances of stopcocks, switches, &c., are to be had at a comparatively small cost, and so easy and safe to manipulate that even the dullest servant cannot fail to learn how to use them. It is true that even now there are people who contrive to produce an explosion of gas, or "an accident" with the electric current, but such occurrences are quite exceptional.

It is often claimed and rightly that coal gas is cheaper as a source

Digitized by Google

of light than all preceding means, and also that electricity is in its turn cheaper than gas, but these statements must be taken with some qualification. It is quite true that coal gas produced on a sufficiently large scale is a cheaper source for a given amount of light than oil or candles; but the light is often less easy to distribute, and in consequence lights of greater intensity are employed, so that the efficient lighting of a given place by means of gas may cost as much or even more than if candles or lamps were used. In a similar way the electric arc for a given amount of light will generally be cheaper than gas, but this concentrated and intensely brilliant light does not admit of a well distributed illumination, so that to adequately light a given area the cost may be greater than it would be if gas were employed.

In both cases the aim is to heat a body of comparatively small volume to a very high temperature, whether that be a flame or an incandescent solid, or, as in the case of the Welsbach light, a refractory solid heated by a non-luminous flame. In the many forms of regenerative gas-burners, this is secured by heating the air, or both gas and air, before reaching the flame, thus greatly increasing the temperature of the latter.

The cost of coal gas is largely influenced by the value of the so-called residual or bye-products, such as coke, tar, and ammonia, which were at one time difficult to dispose of, but are now very valuable sources of revenue. Indeed, there is little doubt that if the consumption of gas were materially reduced, the existing relation between the gas and the subsidiary products would be reversed; coal would be distilled for the production of tar, ammonia, &c., and the gas would become the bye-product. Closely connected with this question is the use of gas for heating purposes, which formed an important section of Vol. I. of CHEMICAL TECHNOLOGY.

A somewhat similar question arises in the consideration of electric lighting, namely, the utilisation of spare power. If the dynamos are only at work for a small portion of each day, and moreover, as it is necessary, in order to obviate interruption from accident, that a portion of the installation at the central station should be in duplicate, the plant would remain idle for a very large proportion of the time. The plant is to some extent utilised during the daytime when the electricity is not required for lighting, by storing up the energy in "accumulators," and there is also a small demand for power to work electric motors.

Digitized by Google

SECTION I.

GAS MANUFACTURE.

BY

CHARLES HUNT.

CHAPTER I.

Early History of Gas Manufacture.

Of all the applications of chemistry to the useful arts, none is, perhaps, more generally appreciated than the production of artificial light from carbonaceous matters; nor can we remember a more striking illustration of the length of time that often passes before a scientific germ is developed into a useful fact, than is exhibited in the early history of illuminating gas.

Numerous instances, both in ancient and modern times, are on record of the spontaneous discharge of combustible gases from fissures in the earth, and there is reason for supposing that some of these natural jets of gas were treated by the ancients as objects of veneration, as they still are by the inhabitants of parts of Persia and India, whilst the practical Chinese have for centuries employed similar combustible exhalations for evaporating salt-brine and lighting their salt works. That the processes resulting in such exhalations are still active under certain conditions, is proved by the formation of marsh gas or methane in every stagnant pool, and by the occasional discovery of accumulations of gas in boring for water. In 1846, an exhalation occurred from the bed of the River Wear near Framwellgate Bridge, the bubbles of which could be readily ignited on the surface of the water. In 1851, when boring for water on Chat Moss, between Manchester and Liverpool, at about 33 feet below the surface, on the introduction of a pipe 10 or 12 inches in diameter, and 36 feet high, into the borehole, gas was conducted above the forest trees, and, when ignited, produced a flame 8 or 10 feet long. But the most remarkable example of the issue of this natural gas from the earth is furnished by the gas wells, occurring in the oil regions of Pennsylvania. These vary in depth, to about 1600 feet, and at Murraysville and Tarentum were supposed to be practically inexhaustible. The gas issues from them at a pressure as high as 160 lbs. per square inch, and is conveyed a considerable distance in pipes 10 to 16 inches, and in one case 36 inches in diameter, to Pittsburg and Alleghany city, where for a time it almost entirely superseded coal as fuel in the manufacturing establishments (see Vol. I., "Fuel," p. 286 *et seq.*). These natural exhalations consist chiefly of marsh gas, which has feeble luminosity, and it is probably owing to this fact that although their origin in this country was traced by Shirley as early as the year 1659 to subjacent coal-beds, no attempt was made to apply either the gas or the coal to illuminating purposes for nearly a century and a half. "Spirit of

Digitized by Google

coal" was, however, obtained from that substance as early as the latter half of the seventeenth century, by Dr. Clayton, then Rector of Crofton, at Wakefield in Yorkshire, who communicated his discovery in a letter to the Hon. Robert Boyle, which, however, was not published until the year 1739, when it appeared in the "Philosophical Transactions" of the Royal Society. The "spirit of coal," or gas obtained by distilling coal in a retort, was collected in bladders, and its combustible and illuminating properties exhibited; yet, notwithstanding this proof of its value, no practical application of the gas as a source of light appears to have suggested itself to the discoverer. In the "Vegetable Statics" of Dr. Hales, published in 1726, a quantitative experiment upon the amount of gas evolved during the distillation of Newcastle coal is described, by which it appears that from 158 grains of coal, Dr. Hales obtained 180 cubic inches of "air," weighing 51 grains, or about one-third the weight of the coal. In 1767, Dr. Watson also published experiments on the quantity of gas yielded by coal, and ascertained that its volume and combustibility were not altered by passing through water. Amusing experiments were also made with the gases evolved from coke furnaces, by the Earl of Dundonald, in 1786. No practical application, however, was made of these discoveries until Mr. William Murdoch, in the year 1792, lighted his own house at Redruth, in Cornwall, with coal gas produced in iron retorts, and conveyed in metal pipes for a distance of 70 feet. This was undoubtedly the first useful application of a discovery which had been made at least a century before, and the success which attended it, and the subsequent labours of Mr. Murdoch, soon resulted in the general introduction of gas, as the best and cheapest source of light, whenever any considerable amount was required. It is but just to mention that the application of the gas obtained from the distillation of wood or coal was proposed independently, and almost coeval in time with Murdoch's invention, by Lebon in France, who both lighted and heated his house by that means. The question of priority, however, is set at rest by the fact that Lebon's first patent is dated 1799, and also that, as all agree, his first exhibition of the light in Paris was in 1802, ten years after the date of Murdoch's successful application of coal gas at Redruth. One great obstacle to the introduction of this source of light into private dwellings had still to be overcome, and this lay in the offensive and injurious properties of some of the products evolved during the combustion of the gas. These, though small in amount, it was found absolutely necessary to remove, either by conveying the whole of the products of combustion to the exterior of the building, or by separating from the gaseous mixture, before it entered the burners, those substances to which the various offensive products owed their origin. The former plan was resorted to in many instances, and, in conjunction with the latter, has been revived in recent times, ventilating burners being employed for removing to the chimney or elsewhere the entire products of combustion. It was not long, however, before an agent was discovered, which to a very great extent removed the sources of the noxious products; and to Dr. Henry and Mr. Samuel Clegg we are indebted for the suggestion of the use of lime as a purifier, which still continues to be employed very largely for this purpose.

In 1798, six years after his first essay, a part of the Soho manufactory of Messrs. Boulton and Watt was lighted with coal gas by Mr. Murdoch, where, on the occasion of the general illumination at the Peace of Amiens in 1802, a public exhibition of the light was made. Shortly afterwards, the cotton mill belonging to Messrs. Phillips and Lee, at Manchester, was wholly lighted by him with the same material, and his experiments on the application of coal gas to illumination were published in the "Philosophical Transactions" for 1808. Stonyhurst College, and also many private manufactories

Digitized by Google

in the country, were lighted about this time by Murdoch and Clegg; whilst the indefatigable—albeit extravagant and over-sanguine—advocacy of gas-light in London, by F. A. Winsor, led to its introduction there, and one side of Pall Mall was lighted by gas in 1807. The great advantages of gaslight for streets and public edifices then became apparent; an application to Parliament for an Act to incorporate a gas company was made in 1809, which, failing, was renewed with success in the following year; and before very long the entire metropolis and most provincial towns were lighted with gas. In the United States, the new source of light was introduced in 1806, and in the course of the following years was adopted in most of the more important towns. In the year 1816, Winsor exhibited the new light in Paris, where, a few years later, it became established.

A short time previously, Mr. John Taylor had secured a patent for obtaining illuminating gas by the distillation of oils and other similar materials; this was acquired and worked by Messrs. Taylor and Martineau; and for some time many extensive establishments adopted the process, which yielded a very superior gas, but at a cost which could not compete with that obtained from coal. Oil gas-works were, however, erected in many towns, but the use of this material was soon relinquished in this country, although it continued to be employed for some time longer in some parts of the Continent, and it is still in use to a limited extent in India. In 1819, a patent was obtained by Gordon and Heard for compressing the gas, so as to render it portable. This scheme was also abandoned after a few years, although the process has been revived, using petroleum or shale oil as the source of gas, and is now extensively employed for lighting railway carriages. Similarly the application of resin for the manufacture of gas was commercially unsuccessful, but it continued to be used in small quantities as an enricher of coal gas, until driven completely out of the field by the increasing abundance of cannel coal. Of recent years, however, the latter has shown signs of approaching scarcity, at least as regards the richer qualities; and the comparative abundance of mineral oil has resulted in its again being somewhat largely employed in place of cannel, chiefly where gas of a high quality is required.

Many schemes have from time to time been proposed for enriching gases by the vapours of hydrocarbons, and in 1847 Mansfield obtained a patent for carburetting air, since which period the subject has been a fruitful one for patents; amongst the most recent of these is the Maxim-Clark process, by which the gas is carburetted with petroleum spirit of very light specific gravity. Coal gas has, in this country, maintained its supremacy, although in many parts of the United States it has been superseded by carburetted water gas to the extent, according to a recent estimate, of about two-thirds of the entire supply of illuminating gas.

In 1810, the first gas company obtained its Act of Incorporation, and commenced operations in the metropolis with a nominal capital of £200,000. Two years later, it was granted a Royal Charter, becoming thenceforth and for nearly sixty years afterwards known as the Chartered Gas Company. Since that period, the growth of gas lighting has proceeded almost uninterruptedly, and has attained enormous proportions. In the year 1850, there were thirteen companies established in London, many of them in active competition with each other, but the evil of this was found to be so great that it became necessary to limit each company to a separate district. Subsequently, legislative pressure was brought to bear upon the companies to induce them to amalgamate, and this eventually led to their fusion into the three—the Gas Light and Coke (formerly the Chartered), the South Metropolitan, and the Commercial—which at present supply the whole of the metropolitan area from nineteen different gas-works. The Board of Trade returns for

Digitized by Google

1898 show that the united capital of these companies, actually invested in their undertakings, has reached £21,898,303. The total length of distributing mains possessed by them is 3208 miles, and their customers number 537,411. To supply these requires an annual production of 34,833,862,000 cubic feet of gas.

Great as is the progress which these figures indicate, it is, in comparison with the population, fully equalled by the record of several of the large manufacturing and commercial centres. Thus the same returns show that the gas-works at Glasgow have a yearly production of 5,355,423,600 cubic feet for the supply of 186,327 consumers; those of Birmingham, 5,530,919,000 cubic feet, and 67,398 consumers; of Liverpool, 3,588,622,000 cubic feet, and 82,200 consumers; of Manchester and Salford combined, 5,846,302,000 cubic feet, and 157,224 consumers; and of Leeds, 2,992,650,000 cubic feet, and 90,970 consumers.

Throughout the United Kingdom, there are, included in these returns, 661 gas undertakings, which employ in the aggregate a capital of £82,109,752, and consume annually, for gas-making purposes, 12,841,817 tons of coal, besides a large quantity of oil for the production of carburetted water gas.

For a long period it was the general experience that gas consumption became doubled about every ten years; and the present rate of increase is still considerable, notwithstanding the general use of more economical burners. At the same time, gas is by no means so general a source of light in private houses —especially in the metropolis and in some of the larger towns in England—as might be expected from its long establishment, convenience, and relative cheapness; a circumstance which may be accounted for in some measure by the restrictive policy occasionally pursued by its purveyors, who, until recently, have had little inducement to extend their business; and by the discomfort which is experienced when gas is consumed in ill-ventilated rooms. The attention now being paid to ventilation, however, coupled with a great improvement in the purity of the gas, has, to a large extent, removed this objection, whilst the additional uses to which it has recently been applied, for cooking, heating, and motive power, have already favourably affected gas revenues, and must contribute to a further development of the undertakings. Moreover, the introduction of incandescent gas lighting among those who otherwise would resort to electricity, and of the penny-in-the-slot meters to the poorer members of the community who might otherwise prefer oil, will no doubt greatly strengthen the industry.

When gas was first supplied by meter, the price charged for it in the metropolis was 15*s.* per thousand cubic feet; but during the first years of their existence the gas companies were far from prosperous, and with some of them it was a hard struggle for existence. It is stated that, as recently as 1852, the £50 shares of one company were not worth more than £2 5*s.* per share, and the fortunes of other undertakings of the same nature were similarly at a low ebb. Their prospects, however, quickly improved after the adoption of the districting arrangements already alluded to, which received the sanction of the Legislature in 1860. In that year, amongst other things, it was enacted that the dividends of the companies should not exceed 10 per cent. per annum, and that all surplus profits, after providing a suitable reserve, should be devoted to reducing the price of gas; the illuminating power to be supplied being fixed at twelve sperm candles, and the maximum price 4*s.* 6*d.* per thousand cubic feet. It was not long before the companies were able to divide the full statutory dividend, which was practically assured to them by the terms they had succeeded in obtaining from the Legislature, and it became needful to apply to them a further incentive to exertion. As the result of protracted Parliamentary inquiry the standard of illuminating power was raised, and three gas referees were appointed, with special charge over all questions relating to the testing and purity of the gas, the maximum price of which was lowered

Digitized by Google

to 3*s.* 9*d.* per thousand cubic feet. Power, however, was given to the companies to apply to Commissioners appointed by the Board of Trade for a revision of price should circumstances arise to prevent them from earning their maximum dividend. By two of them this power was exercised after the coal famine of 1872–73, and their action in this respect, with its result in greatly raising the price of gas, led to further Parliamentary inquiry. This resulted, in 1875–76, in the adoption of what is known as the sliding scale, by the enactment of which, the dividends of the principal metropolitan companies became directly dependent on the selling price of their gas, it being provided that these should be raised or lowered to the extent of a quarter per cent. for every decrease or increase of 1*d.* from the fixed standard price of the latter. This ultimately became the law for the whole of the metropolis, the standard of quality being at the same time made uniformly sixteen candles; and its operation has been distinctly beneficial, as shown by the gradual reduction in price that has taken place. Similar legislation has been applied to many provincial undertakings, but the great development in the provinces of local government has led, in no fewer than 192 instances, to the acquisition of the gas undertakings by the governing bodies. This has generally resulted in the realisation of a large annual profit, applied, as at Manchester, Birmingham, and other towns, to the relief of the rates, or street improvements; but in a few cases the practice prevails of devoting all profits to further reduction in the price of gas. At Leeds, the effect of this policy was to lower the price to 1*s.* 8*d.* per thousand cubic feet, being the lowest in the kingdom; and it remained at this for several years, until in 1889 a revision became necessary owing to the great advance in the price of labour and materials of all kinds.

CHAPTER II.

Process of Gas Manufacture.

The various steps in the process of gas manufacture will be made clear by referring to the plan and section of a modern gas plant, Plate I. The coal, in charges of from 2 to 4¼ cwts. at a time, according to the capacity of the retorts, is placed in the retorts AAA, which are previously heated to the required temperature by means of a suitable furnace B. The coal is often thrown with shovels into the hot retorts, but usually steel scoops, holding about 1¼ cwt. of coal, are employed. These require three men to work them. Being previously filled with coal, a man on each side of the scoop lifts the end of it by means of a tool called a "horsing-in iron" into the mouth of the retort, while a third, who holds the rod and handle attached to the other end of the scoop, pushes it forward to the end of the retort; the contents are then turned out by inverting the scoop, which is quickly withdrawn, and a second scoop, which has been previously filled, inserted, the operation being repeated, if necessary, until the retort is fully charged, when the lid is closed and made secure. Very little time is thus consumed in charging, two, or at most three, scoopfuls being sufficient for a charge; moreover, the retorts are not so long exposed to the cooling action of the air as when shovels are used. In the results, however, obtained by each method little, if any, difference is observable. The shovel is at many works preferred to the scoop.

The process of carbonisation requires from three to eight hours according to the nature of the coal, the heat employed, and the shape and size of the retort; when finished, the lid is slacked; the gas contained in the retort then ignites, or is ignited by applying a red-hot rod called a "torch"; and the glowing coke is raked out and water thrown on to it, the retort being recharged as quickly as possible. When, as is most practicable with regenerative furnaces, the portion of coke required for fuel is employed as it

Digitized by Google

is taken red-hot from the retort, all the heat required to raise it to redness is economised.

Were the coal gas as it issues from the retort pure, little additional apparatus would be required; but it is associated with various impurities, for the elimination of which most of the following apparatus is provided. CC are the mouthpieces of the retorts, each furnished with an outlet, or ascension-pipe C′C′, through which the gaseous products pass to the hydraulic main D, where a large portion of the tar is deposited. From the hydraulic main the gas is conducted by means of the "foul" main E to the condensers, Fig. 1, where it becomes cooled to about the temperature of the atmosphere, and deposits tar and aqueous vapour. The tar and ammoniacal liquor—that is, water which has absorbed ammonia, &c.—flow to the separator F, the liquor being conveyed to the washer G, into which the gas is conducted after leaving the condensers, for the purpose of removing a further portion of the ammonia and other impurities, together with any remaining traces of tar. This is effected by breaking up the gas, and causing it to pass in minute bubbles through an appreciable depth of liquor. By the pipes HH shown on plan, the tar from the separator, and the liquor which has passed through the washer, are conveyed tothe tar well or storage tank, Fig. 2, from which they are pumped up as required, either for sale or for distillation upon the premises. From the washer, the gas passes to the exhauster J, although in some works the scrubber is next employed, and in others both the washer and the scrubber are placed after the exhauster. In either position, the effect of each is the same; the object to be kept in view in selecting it being to supply the washer with liquor by gravitation from the condensers or scrubber, or both, as may be found convenient, and so avoid the necessity of pumping from the storage tank; while by deferring the washing processes until after the gas has passed through the exhauster the small quantity of tarry matter carried forward by it sometimes acts with advantage as a lubricant. The function of the exhauster is to remove the gas from the retorts as rapidly as it is produced, so as to reduce the pressure as much as possible, and thus avoid the loss which would otherwise ensue from leakage, and by the deposition of carbon upon the sides of the retorts. At the same time, the action of the exhauster forces the gas onwards through the remaining apparatus, and thence into the gasholders. In the scrubber S, the gas is brought into contact with a large extent of freshly wetted surfaces, arranged in series, liquor highly charged with ammonia meeting the gas at its entrance, then liquor which is less strong, and so on until the outlet for the gas is reached, at which point clean water is admitted. This operation removes all ammonia from the gas, in combination with large quantities of carbonic acid and sulphuretted hydrogen, so that both the scrubber and the washer play an important part in the removal of these impurities. The purifiers, KKKKKK, through which the gas next passes, used for the elimination of carbonic acid, sulphuretted hydrogen, and carbon bisulphide, are a series of rectangular cast-iron vessels four feet and upwards in depth, with removable wrought-iron covers. They are provided with two or more trays, not less than twelve inches apart, upon which the purifying material is placed. The material used may be either lime alone, oxide of iron alone or in conjunction with lime, or lime in conjunction with oxide of iron and calcium sulphide, according to necessity or wish, as will be explained later on. After leaving the purifiers the gas is conveyed to the station meter L, where the production is registered, and from thence it passes into the gasholder, Fig. 3, in which it is stored for use as required. It is necessary to regulate the pressure at which the gas enters the distributing mains, and for that purpose the governor M is fixed at or near the outlet of the gasholder.

The illuminating power of a mixture of gases depends on the quantity

Digitized by Google

Digitized by Google

Digitized by Google

and nature of the hydrocarbons contained in it, and to a smaller degree on the nature of the diluting gases with which these are mixed.

The value of a hydrocarbon as an illuminant depends, first, on the ratio of carbon to hydrogen, and, secondly, on the number of carbon atoms in each molecule.

CHAPTER III.

Gas Coal.

THE nature of the coal which is submitted to carbonisation in the manufacture of gas exerts such a decided influence both on the quantity and on the quality of the gaseous product, that, notwithstanding the numerous and extensive series of coal analyses already contained in Vol. I. ("Fuel"), it is advisable to add others made especially with reference to the coals used in gas-making; these have been for the most part extracted from the very complete tables in King's treatise on Coal Gas, and "Notes on the Lithology of Gas Coals," by James Paterson.

Various Cannel Coals, Analysed by Dr. Penny.

Cannel or Parrot Coals.	Coal.						Coke.		
	Sp. Gr.	Volatile Matters.	Fixed Carbon.	Ash.	Sulphur.	Water.	Total Amount of Coke in Coal.	Carbon in Coke.	Ash in Coke.
		Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.	Per Ct.
1. Rochsoles (1851)	1.448	53.7	4.9	38.8	1.6	1.0	42.3	11.58	88.42
2. Hardie's (1852)	1.420	34.0	4.0	58.4	*	3.5	62.4	6.44	93.56
3. Boghead, Brown (1851)	1.160	71.06	7.10	26.2	0.24	0.4	28.3	25.09	74.91
4. Boghead, Black (1851)	1.2185	62.7	9.25	26.5	0.35	1.2	35.75	25.88	74.12
5. Torbanehill (1853)	1.1892	67.11	10.52	21.0	0.32	1.05	31.52	33.38	66.62
6. Boghead (1849)	1.1550	71.3	11.3	16.8	(0.34)	0.6	28.1	40.22	59.78
7. Bathville	1.201	64.35	12.6	22.2	0.25	0.60	34.80	36.21	63.79
8. Stan (Ayrshire)	1.4647	52.08	14.77	32.0	*	1.15	46.77	31.52	68.48
9. Methill	1.3002	49.23	17.57	29.7	*	3.50	47.27	37.17	62.83
10. Capeldrae	1.3603	45.73	19.97	31 5	*	2.80	51.47	38.80	61.20
11. Wemyss	1.1831	58.52	25.28	14.25	*	1 95	39.53	63.95	36.05
12. Balbardie (1852)	1.420	38.96	29.66	28.0	0.38	3.0	57.66	48.56	51.44
13. Hillhead (Kilmarnock)	1.602 / 1.320	36.65	32.34	27.4	0.61	3.0	59.74	54.14	45.86
14. Brymbo	*	32.10	36.4	29.4	*	2.1	65.50	55.32	44.68
15. Lesmahagow (Auchinheath)	1.1990	56.23	36.7	4.3	0.55	3.15	41.0	89.50	10.50
16. Bartonshill	1.280	48.0	39.6	10.0	2.0	2.4	49.6	79.84	20.16
17. Bartonshill	1.350	38.0	37.9	18 7	2.2	3 2	56.6	66.96	33.04
18. Stevenson (Ayrshire)	1.3850	40.21	40.14	19.35	*	0.3	59.49	67.64	32.36
19. Lesmahagow (Southfield)	1.228	49.34	40.97	6.34	1.35	2.0	47.31	86.60	13.40
20. Knightswood	1.234	44.77	41.13	11.05	*	3.05	52.18	78.83	21.17
21. Cairnbroe	1.247	42.83	42.67	8.50	*	6.0	51.17	83.39	26.61
22. Skaterigg	1.252	49.32	44.83	2.50	*	3.35	47.33	94.42	5.58
23. Cowdenhill	1.299	46.0	45.0	5.0	0.50	3.50	50.0	90.0	10.0
24. Breadisholme	1.335	39.0	48.5	8.1	04	4.0	56.6	85.69	14.31
25. Ruchill	1.223	45.73	49.27	2.5	*	2.5	51.77	95.17	4.83
26. Kelvinside	1.231	40.17	53.42	1.9	0.21	4.3	55.32	96.57	3.43

* Not estimated.

Digitized by Google

Name of Coal.	Cubic Feet of Gas per ton.	Illuminating Power. Candles.	Sp. Gr. Air = 1.000.	Lbs. of Coke per ton.	Ash in Coke per cent.
Cannels.					
Arniston	12,600	22.50	0.626	1221	7.66
Boghead	13,334	45.00	—	717	—
"	15,000	37.75	0.752	708	72.15
Capeldrae	14,400	19.75	0.577	1019	23.07
Chapelside, Airdrie	11,272	35.61	—	916	19.08
Haywood, Scotch	11,400	30.22	—	1157	17.8
Kirkness	12,800	21.20	0.562	8 6	33.7
Knightswood	13,200	19.00	0.550	1154	4.66
Lesmahagow, No. 1 Cannel	13,500	27.10	0.642	1129	18.05
" No. 2 "	13,200	24.80	0.618	—	—
Leverson	11,600	18.00	0.523	1550	13.51
Pelton	11,500	18.50	0.520	1534	13.72
Wemyss	14,300	24.50	0.580	1064	31.78
Newcastle Coals.					
Leverson's Wallsend	10,800	12.50	0.425	1458	7.52
New Pelton	10,500	12.00	0.415	1564	2.50
Pelton	11.000	14.00	0.430	—	—
Pelaw	11,000	12.75	0.420	—	—
West Hartley	10,500	12.50	0.420	1438	7.30

Analyses of Coals (Fiddes).

Name of Coal.	Cubic Feet of Gas per ton.	Illuminating Power. Candles.	Lbs. of Coke per ton.	Ash in Coal per cent.	Sulphur in Coal per cent.	Hydrocarbon absorbed by Bromine, per cent.
Welsh Coals.						
Llantwit	10,285	16.56	1524	4.85	1.42	5.00
Rhos Llantwit	9,730	17.07	1417	2.33	1.64	—
Llantwit Red Ash	9,708	18.33	1344	4.90	1.35	6.46
Nantgarw Llantwit	9,791	16.64	1379	3.78	3.45	5.20
Varteg Hill Cannel	9,262	19.21	1366	8.33	2.32	6.20
" " Gas Coal	9,021	17.47	1335	9.12	2.32	5.80
New Tredegar	9,910	14.30	1715	1.61	3.20	4.33
Energlyn	9.960	17.85	1597	2.30	1.87	5.75
Holly Bush	10,577	12.51	1666	3.50	2.28	3.10
Tyr Filkens	11,835	15.60	1452	3.90	2.54	4.30
Llanhilleth	9,480	16.43	1576	1.31	1.64	—
Aber Rhondda	9,680	14.00	1585	6.89	3.67	2.71
Wallsend	9,990	17.84	1478	4.82	1.86	6.10
Gloucestershire Coals.						
Coleford High Delf	9,150	16.13	1402	6.70	1.67	4.25
New Bowson, Cinderford	9,220	17.80	1303	4.76	1.94	5.20
Hanham	9.979	14.37	1318	11.48	2.44	4.75
Yate	10,360	15.61	—	5.98	—	—
Coal Pit Heath	8,262	18.18	—	13.74	—	—
Warmley	8,990	15.50	1593	5.83	0.87	4.95
Parkfield	9 012	19.30	1365	3.53	1.44	5.25
Somersetshire Coals.						
Paulton	9,240	15.57	1249	17.20	—	4.20
Radstock	10,270	18.32	1308	5.94	—	—
Clutton	8,901	17.51	—	6.28	—	—
Nailsea	9,334	16.61	1484	3.68	2.37	4.35

Digitized by Google

Gas Coals, Analyses by Mr. James Paterson.

Name of Coal.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Coals in lbs. of Sperm.	Sulphur in Coal. Per cent.	Coke per ton. lbs.	Ash in Coke. Per cent.
Abram Colliery Co., Wigan, 4 ft.	Wigan	10,250	15.62	549.	—	1,307	5.66
" " " 5 "	"	11,000	14.	532.8	—	1,315	7.05
" " " 6 "	"	10,500	15.76	567.36	—	1,361	6.88
" " " Arley	"	10,500	16.50	594.57	—	1,463	3.50
Albert Colliery, Chesterfield Gas Coal	Newbold	10,375	14.13	501.	—	1,402	3.33
Alliance Coal Co., King Coal	Wigan	9,325	14.30	471.	1.900	1,453	5.31
Ardenton Hall, Arley Nuts	"	11,500	18.80	583.	—	1,485	2.72
Aston Hall, Gas Coal	Hawarden	8,820	16.46	483.	—	1,384	2.38
" Premier Coal	"	11,250	16.77	623.43	—	1,368	3.37
Aston Moss Colliery, 4 ft.	Manchester	12,500	14.50	621.42	1.019	1,496	4.15
" " 6 "	"	12,700	15.	653.	0.517	1,528	4.50
Atherton Colliery, Arley	Leigh	11,500	14.66	576.	—	1,422	3.77
Barley Brook, Arley	Wigan	9,500	16.70	544.	2.08	1,459	4.59
Barrow, Silkstone	Barnsley	11,250	14.84	572.40	0.07	1,527	0.80
" Thornton Thin Seams	"	12,050	14.28	590.71	0.04	1,495	1.00
Bestwood Coal and Iron Co., Gas Coal	Nottingham	9,540	15.14	495.21	—	1,282	6.72
Bersham Colliery—							
Gas Coal, Old Pit	North Wales	10,600	14.50	527.	—	1,336	4.12
Main Coal, New Pit	"	12,100	16.94	702.76	0.240	1,321	5.65
Quaker Coal	"	12,000	15.52	638.54	0.243	1,368	12.37
Bickershaw Colliery, Crombouke	Leigh	11,650	16.40	655.	0.504	1,250	9.25
" " Wigan, 4 ft.	"	11,400	16.90	660.55	1.17	1,320	8.62
" " " 6 "	"	11,350	15 61	607.45	0.095	1,320	4.51
" " " 7 "	"	10,650	16.56	604.	0.667	1,320	1.85
Birley, Silkstone	Barnsley	12,450	16.27	688.78	—	1,463	1.68
Bishwell Coal and Iron Co.	Swansea	11,400	14.21	555.34	0.103	1,464	6.20
Black Bed Coal	Dewsbury	11,900	16.65	665.	0.735	1,432	6.55
Blackey, Hurst, Little Delph	St. Helens	9,725	13.81	460.	—	1,470	2.75
Blainscough Colliery, Arley	Wigan	11,970	16.39	672,65	—	1,433	3.23
Boythorp, Silkstone	Chesterfield	11,300	14.75	571.46	—	1,320	3.13
Brinsop Hall, Arley	Wigan	9,980	16.45	566.30	0.878	1,444	3.60
Broughton Coal Co., Gas Coal	Wrexham	11,800	15.07	609.70	—	1,340	3.00
Brown, John, and Co.—							
Aldwake Main (Brights)	Sheffield	12,600	19.	820.80	0.300	1,428	3.64
" " (Hards)	"	11,000	19.70	742.97	0.298	1,403	4.77
Carr House (Hards)	"	10,790	19.28	713.26	0.255	1,405	4.10
" (Softs)	"	12.475	14.43	617.19	0.579	1,375	6.35
Brunington New Main	"	11,020	15.43	583.	—	1,411	3.21
Brynn Hall, Hard Coal	Wigan	9,540	15.28	500.	1,131	1,377	5.64
" Gas " (Brights)	"	10,800	16.14	597.	—	1,324	5.50
" Arley	"	11,250	14.55	561.21	—	1,428	2.46
" Gas Nuts	"	11,700	14.13	566.78	—	1,345	5.33
Byron Colliery	Carlisle	12,400	15.26	648.77	0.971	1,400	7.72
Chapel House Colliery—							
Russia Park	Skelmersdale	12,300	15.27	644.	0.300	1,400	8.66
Park Mine	"	11,700	15.	602.	0.450	1,353	6.26
Chesterfield and Boythorpe, New Steam	Chesterfield	10,750	1711	630.63	3.886	1,340	17.00
Clifton Hall	Wigan	10.730	17.30	636.44	—	1,464	3.33
Collins Green	St. Helens	10,600	14.68	533.51	—	1,368	6.6
Coop and Co., King Coal	Wigan	9,325	14.30	471.	1.412	1,453	5.31
Cross, Tetley and Co., Wigan, 4 ft.	"	10,000	14.40	608.	0.535	1,336	4.00
Crow Colliery, Ormskirk Park Mine	"	11,300	16.16	626.	1.306	1,370	3.35
Coed Talon Yard Coal	Mold	10,250	16.96	595.68	1.476	1,310	7.2
Davies, Joseph, Gas Coal—							
Bottoms	Wigan	10,230	15 11	530.	—	1,437	3.33
Middles	"	10,300	15.40	543.	—	1,500	2.61
Tops	"	11.300	16.81	651.27	—	1,497	2.41
Denaby Main Colliery, Gas Coals—							
Screened	Rotherham	12,300	16.00	676.17	0.279	1.336	4.
Unscreened	"	12,000	14.68	604.	0.153	1,384	5.

Digitized by Google

Name of Coal.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Coals in lbs. of Sperm	Sulphur in Coal. Per cent.	Coke per ton. lbs.	Ash in Coke. Per cent.
Derbyshire Coal Co., Gas Coal	Rotherham	10,775	14.71	543.37	—	1,465	nearly 6.
" " Silkstone	"	11,020	15.43	583.	—	1,411	3.21
Ditton Coal and Iron Co., Middle Mountain Mine	St. Helens	10,055	17.26	595.	—	1,470	1.73
Duxbury Park Gas Coal	Wigan	9,500	16.70	544.21	1.864	1,460	11.70
Ebbw Vale Coal and Iron Co.—							
Meadow Vein	Monmouthshire	10,000	15.33	526.60	—	1,560	7.62
Rock Vein Coal	"	11,350	14.52	565.	—	1,495	5.33
Red Ash "	"	11,800	15.	607.	—	1,466	3.35
Evans, R., and Co., Arley	Wigan	12,100	16.89	700.7	0.811	1,370	3.
Fisher, B. and R., Anderton Hall, Arley	"	11,575	14.95	593.30	0.564	1,416	2.85
Fletcher, Burrows and Co., Arley	Atherton	11,450	16.29	639.5	2.75	1,420	2.75
Fodbank, Fifeshire, Gas Coal	Dunfermline	10,530	14.41	550.57	—	1,245	5.21
Fox Field Colliery	Staffordshire	11,900	16.50	673.20	1.242	1,245	4.66
" Park Coal Nuts	"	11,000	14.30	540.	—	1,527	19.33
" " Liversedge	"	10,900	15.13	565.43	—	1,495	16.66
Grange Silkstone	Rotherham	11,533	16.82	665.	0.346	1,417	4.15
Garswood Coal and Iron Co.—							
Orrell, 4 ft.	Wigan	11,300	14.91	577.65	—	1,433	2.50
" 5 "	"	11,350	15.62	609.46	—	1,368	1.50
Garswood, Little Delph	St. Helens	9,000	14.74	455.17	0.768	1,419	3.
Grosvenor Colliery, N. Wales—							
Gas Coal, Tops	Wrexham	12,050	14.48	596.26	—	1,336	4.22
" Bottoms	"	12,225	14.87	609.20	—	1,307	5.31
Haddock, Little Delph	St. Helens	8,936	12.75	391.	—	1,398	3.03
Hazlewood Coal and Cannel Co.	Mold	10,500	14.81	533.15	5.1	1,282	5.1
Hicbibi Coal Co., Ellerbeck	Wigan	12,100	15.	622.28	—	1,400	4.32
" " Best Coal	"	11,300	14.25	522.	—	1,373	3.11
" " Arley, 6 ft.	Chorley	11,800	14.05	598.	1.00	1,340	3.30
Higson, J. and P.—							
Dukinfield Black Mine	Dukinfield	12,100	16.03	665.	0.319	1,495	2.70
Lille Black "	"	12,000	15.	617.14	0.421	1,495	2.95
Peacock "	"	11,100	14.30	544.21	0.594	1,488	4.55
Hindley Field Gas Coal	Wigan	10,700	15.26	562.	—	1,314	5.45
" " Wigan, 4 ft.	"	10,750	15.35	565.73	—	1,374	7.77
Hindley Green, Arley	"	11,200	15.11	585.60	—	1,425	2.28
" " 5 ft.	"	9,470	13.35	409.10	—	1,315	3.21
Hindley Hall, King Coal	"	11,550	15.36	608.26	—	1,435	2.11
" " Gas "	"	11,050	13.17	498.83	1.00	1,370	4.22
Ince Hall, Wigan, 4 ft.	"	10,840	16.52	614.	0.488	1,382	5.17
Johnson, Edward—							
Wigan, 4 ft.	"	9,950	15.44	526.72	0.854	1,336	5.47
" 5 "	"	11,050	13.34	505.38	—	1,326	4.11
Golborne Gas Coal	"	10,650	17.40	635.35	1.253	1,315	3.
Kirkless Yard Coal	"	9,730	15.32	511.10	1.241	1,464	4.23
Lidgate Colliery	Barnsley	10,500	16.68	600.48	1.954	1,368	4.50
Manver's Main	Rotherham	11,600	17.20	684.	0.213	1,310	4.23
" " Gas Coal	"	11,000	16.62	627.	—	1,366	2.02
Micklefield Colliery Co.	Leeds	10,800	15.55	671.	1.32	1,275	8.
Milton "	Carlisle	12,400	15.26	648.77	0.971	1,400	7.72
Mirfield Coal Co., Coal, Cannel Mixed	Mirfield	12,600	16.67	720.	—	1,430	1.88
Moss Hall Gas Coal	Wigan	10,800	16.75	620.23	1.183	1,444	2.32
" 4 ft., 10 p.c. Cannel	"	10,800	16.7	618.38	0.340	1,274	4.93
" Arley	"	11,300	14.51	562.55	0.625	1,416	3.75
Mountain Mine Coal Co.	St. Helens	11,250	17.31	667.06	0.163	1,550	2.
Neston Colliery Co., Gas Coal	Cheshire	10.400	16.48	588.34	—	1,320	4.10
Newent Coal and Iron Co.	Gloucester	11,200	14.30	549.12	1.153	1,049	3.45
Newton Chambers and Co.—							
Norfolk Silkstone	Thorncliffe	13.300	15.14	694.18	—	1,331	0.79
Silkstone Nuts	"	13,200	14.54	658.	—	1,440	0.88
" Thin Seam	"	12,500	14.27	611.57	—	1,366	1.32
" Tops and Bottoms	"	12,370	14.19	601.82	—	1,466	1.00
Rockingham Silkstone	"	12,500	14.45	605.33	—	1,432	2.32
Best "	"	12,180	16.38	683.82	—	1,441	1.57

Digitized by Google

Name of Coal.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Coals in lbs. of Sperm.	Sulphur in Coal. Per cent.	Coke per ton. lbs.	Ash in Coke. Per cent.
Newton Chambers and Co.—							
Screened Gas Coal	Thorncliffe	12,350	16.	677.49	—	1,400	1.30
„ Parkgate Softs	„	11,570	16.50	654.40	—	1,450	0.93
„ Silkstone „	„	11,500	16.75	660.43	—	1,482	0.79
New Winning Orrel, 4 ft.	Wigan	10,975	16.97	638.43	—	1,464	4.33
„ „ 5 „	„	11,800	13.92	563.	—	1,461	5.88
„ Wigan, 4 ft.	„	10,150	14.63	509.12	—	1,400	6.13
„ King Coal Tops	„	10 300	14.53	513.53	—	1,460	5.22
„ „ Bottoms	„	10,000	14.48	497.	—	1,431	5.33
New Zealand, West Coast of Otago	—	11,525	14.95	590.75	—	1,400	2.48
Nunnery Colliery, Gas Coal	Sheffield	11,100	17.70	673.93	—	1,430	3.50
Pearson and Knowles—							
Arley	Wigan	11,300	16.37	634.25	—	1,420	3.63
Smithy Coal	„	10,800	15.22	563.	—	1,463	2.11
King „	„	10,050	14.87	512.40	0.383	1,432	5.27
Peasley Cross, Potato Delph	St. Helens	11,500	14.75	581.60	1.015	1,293	7.95
Pelsall Coal Co., Gas Coal	Sheffield	11,500	15.31	603.65	—	1,320	2.44
Pelton Main, Chester-le-Street, Durham	Durham	11,600	17.66	702.62	1.101	1,560	3.25
Phœnix Colliery Co., Pigeon-house Coal	St. Helens	11,480	16.18	636.84	—	1,330	4.37
Plumbley, Silkstone	Chesterfield	10,750	17.42	648.	—	1,370	6.
„ „ Nuts	„	10,800	16,93	627.	—	1,370	4.20
Pope and Pearson—							
Screened Silkstone	West Riding	12,750	15.26	667.	—	1,368	2.44
Unscreened „	„	12,700	14.95	651.	—	1,371	3.18
Hard Coals	„	10,900	15.50	579.26	—	1,368	7.31
Ravenhead, Upper Delph	St. Helens	10,425	15.61	557.94	0.738	1,305	4.70
Roscoe and Lord—							
Mountain Mine	Farnworth	11,850	15.34	623.24	—	1,460	0.64
Trencherbone Coal	„	11,150	17.	650.	—	1.462	3.12
One-foot Mine	„	11,600	14.96	595.	—	1,545	0.61
Rose Bridge Colliery, Arley	Wigan	12 600	15.40	666.	—	1,493	1.71
„ Yard Coal	„	10,300	15.22	537.51	—	1,315	2.30
„ Wigan, 4 ft.	„	10,120	15.21	527.68	—	1,356	6.87
Rylands and Son, Gidlow, Arley	„	11,350	15.31	597.	0.482	1,463	4.
Sankey-Brook Coal, St. Helens, 4 ft.	St. Helens	9,200	16.47	519.51	—	1,368	3.
Shakerley Colliery Co., Great—							
7 ft. Tops	„	12,050	13.97	577.20	—	1,310	4.44
„ Bottoms	„	11,800	13.25	536.	—	1,305	5.41
Shakerley, Ramsden's Gas Coal	Tyldesley	10,275	17.58	608.75	—	1,283	4.51
Sheepbridge Coal and Iron Co.	Chesterfield	10,800	15.53	575.	0.841	1,428	5.07
Sherdley Colliery, Potato Delph	St. Helens	11,500	14.75	581.60	0.383	1.293	7.95
Shirland „ Gas Coal	Alfreton	11,000	13.46	507.	—	1,312	1.85
„ „ Tipton Gas Coal	„	9,800	16.22	545.	—	1,402	1.77
Silkstone and Dodworth Coal and Iron Co.—							
Old Silkstone	Barnsley	12,240	16.66	699.15	—	1,498	0.88
Parkgate Coal	„	11,220	15.87	610.70	—	1,430	1.62
Silkstone and Stockton Gas Coal	„	12,000	16.62	684.	—	1,432	2.11
„ „ Haigh Moor Coal Co.	Castleford	11,100	17.01	647.35	1.00	1,300	4.87
Smethurst, D. H., and Co.—							
Arley	Wigan	10,250	16.33	576.60	0.881	1,400	3.33
Hardsplint	„	10,980	16.78	620.	—	1,435	5.67
Wigan, 4 ft.	„	10,820	16.	593.56	0.633	1,346	5.79
Gas Coal	„	11,050	14.14	545.50	—	1,420	3.37
South Yorkshire Coal Co., Old Silkstone	Barnsley	12,300	16.73	705.53	—	1,456	1.23
Spring Colliery Yard Coal	Wigan	10,450	13.31	476.22	—	1,456	3.62
„ „ Smith „	„	9,800	15.22	511.39	—	1,463	2.11
St. Helens Colliery, Rushy Park	St. Helens	11,100	14.37	539.14	—	1,370	2.50
„ „ Little Delph	„	11,100	14.39	547 66	—	1,370	2.37
Staveley, Gas Coal, Tops	Derbyshire	9,040	11.52	350.	—	1.395	4.32
„ „ Bottoms	„	10,100	12.23	424.	—	1,340	4.50
Strafford Colliery Co., Silkstone	Barnsley	13,050	14.75	660.	0.112	1,432	3.92

Digitized by Google

Name of Coal.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Coal in lbs. of Sperm.	Sulphur in Coal. Per Cent.	Coke per ton. lbs.	Ash in Coke. Per Cent.
Swan Lane Colliery, Gas Coal	Wigan	9,400	16.82	542.50	—	1,314	2.42
Snydall Hall, Arley	"	10,150	17.80	630.	—	1,291	3.22
Tawd Vale Colliery Co.—							
Gas Coal	Ormskirk	10,420	15.64	558.75	—	1,360	4.22
Rushy Park	"	11,200	14.50	556.80	—	1,400	3.24
New Arley	"	10,300	16.96	575.	—	1,431	2.78
Tyldesley Coal Co.—							
Crombouke	Wigan	9,800	15.64	525.50	—	1,320	2.63
Gas Coal	"	10,600	16.	581.50	—	1,320	2.50
" Bottoms	"	10,600	17.05	619.64	0.8	1,290	4.28
Unston Colliery Co.	Sheffield	10,375	13.57	482.73	—	1,400	2.00
Vauxhall Colliery, Wall and Bench	Ruabon	12,300	14.39	606.82	—	1,463	3.41
Victoria Colliery, Rushy Park	Rainsford	10,030	13.63	454.	—	1,264	2.88
Waterloo Main Silkstone	Leeds	10,800	17.62	652.60	1.149	1,256	5.30
" Silkstone Nuts	"	12,100	14.66	608.46	1.861	1,338	6.95
" Beeston Gas Coal	"	11,200	15.73	604.	0.382	1,308	5.75
Wells Birch, Ryde and Co.—							
Hard Coal	Barnsley	11,600	18.20	723.70	—	1,447	2.50
Soft "	"	10,450	16.88	604.78	—	1,525	13.50
Old Silkstone	"	11,500	18.50	729.42	—	1,463	1.50
West Lancashire Colliery Co., Gas Coal	"	9,700	14.54	480.84	—	1,338	4.11
Wharncliffe Silkstone	"	12,600	16.21	700.	—	1,418	0.95
" Parkgate Coal Tops	"	12,750	16.95	740.96	0.653	1,460	7.00
" " Hards	"	12,500	15.20	651.80	0.300	1,463	8.
" " Silkstone	"	13,000	16.	713.	0.244	1,527	4.90
Wharncliffe Silkstone Colliery Co.—							
Flockton Coal	"	11,550	17.16	679.53	0.798	1,431	6.65
Waids Upper Seam Coal	"	11,200	18.18	698.11	1.088	1,463	7.00
White Moss Co., Park Mine Coal	Ormskirk	11,400	15.37	586.45	—	1,423	2.31
Wigan and Whiston Gas Coal	Wigan	9,750	13.75	459.64	—	1,412	2.94
" " Rushy Park	Prescot	10,300	15.	529,71	—	1,441	1.87
Wigan Coal and Iron Co.—							
Arley	Wigan	11,840	15.37	620,75	—	1,449	1.79
Lady Lane, Arley	"	12,000	16.10	662.40	—	1,428	2.02
Gedlow "	"	11,200	16.4	631.20	—	1,495	5.20
Hindley "	"	11,800	16.84	681.36	0.320	1,430	2.00
Winstanley Colliery	"	10,650	16.26	593.58	0.402	1,368	8.50
Woodleford Gas Coal	Leeds	12,200	16.	614.40	1.173	1,305	6.30

Cannels, Analyses by Mr. James Paterson.

Name of Cannel	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Cannel in lbs. of Sperm.	Sulphur in Cannel. Per cent.	Coke per ton.	Ash in Coke. Per cent.
Abram Coal Co., Wigan, 4 ft., Cannel	Wigan	14,800	29.23	1483.21	—	1,024	5.08
Alliance Coal Co., Wigan, Cannel	"	12,830	20.71	911.	—	1,370	4.88
" Stone "	"	10,500	18.24	656.64	—	1,241	9.21
Bersham Coal Co.—							
Bersham Cannel	North Wales	12,450	15.35	965.23	—	1,180	3.33
New Pit	"	13,000	22.83	1017.57	0.209	1,248	5.90
Bestwood Coal Co., Bestwood Cannel	Nottingham	11,680	18,21	729.17	—	1,209	19.83
Bickershaw Coal Co., 4 ft.	Manchester	12,800	28.64	1256.88	0.239	900	8.25
Blundell and Son—							
Wigan Cannel	Wigan	11,870	22.78	927.08	—	1,415	4.37
Pemberton Cannel	"	12,400	21.80	927.	0.727	1,305	4.80
Boghead, Black Variety	Scotland	15,750	38.39	2073.	—	817	68.21
Bournes and Robinson	St. Helens	13.500	22.23	1032.79	0.290	1,384	6.525

Digitized by Google

Name of Cannel.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Cannel in lbs. of Sperm.	Sulphur in Cannel. Per cent.	Coke per ton.	Ash in Coke. Per cent.
Bowers, Allerton Cannel	Leeds	11,400	20.43	798.52	—	1 300	8.21
Bower, T. and R., Woodleford Cannel	"	11,500	19.	749.14	1.288	1,209	7.0
Brancher and Co, Wigan Cannel	Wigan	12,770	22.20	972.34	—	1,402	4.48
Broadway Colliery, Broadway Cannel	Mold	10,785	16.52	611.	—	1.288	5.33
Bromilow, D., and Co., St. Helens	St. Helens	11,100	21.64	823.56	0.441	1,340	5.60
Bromley, U., Leeswood, Curley	Mold	15,865	28.66	1559.83	0.634	913	29.73
" " Smooth	"	11,570	19.87	788.41	1.034	1,200	7.68
Brown, John, and Co.—							
Band of Cannel in Coal	Sheffield	9,150	20.68	644.80	—	1.463	35.50
Main Seam	"	10,300	18.	635.66	—	1,435	21.1
Brynn Hall, 4 ft.	Wigan	12,350	30.82	1305.57	0.241	1,050	8.22
Coed Talon, Smooth Cannel	Mold	10,800	22.67	898.	0.735	1,344	69.
" Curley "	"	13,600	27.75	1294.	0.680	903	68.70
Crawshaw and Warburton	Yorkshire	10,850	28.6	1063.9	1.325	1.273	11.40
Crippin, W. and F., 4 ft., Cannel	Wigan	12,200	14.31	598.57	—	1,360	3.63
Cross, Tetley and Co., Wigan, 4 ft., Cannel	"	14,200	29.40	1431.36	0.488	1,025	9.50
Ebbw Vale Coal and Iron Co.	Monmouthshire	11,270	19.57	756.12	—	1,463	6.32
Edge Green Coal Co., Edge Green Cannel	Wigan	10,540	19.63	708.	1.010	1,348	7.83
Ellis, Lever and Co., Shirland Cannel	Alfreton	11,600	19.36	769.97	1.211	1,241	3.65
Fiddler, Edward, Coppa Smooth	Mold	11,700	19.62	787.24	—	1,180	6.50
" " " Curley.	"	16,000	27.55	1511.31	0.580	900	33.
Firtree Colliery, 4 ft., Cannel	Wigan	11,900	15.75	643.	—	1,210	13.70
Fletcher, Burrows and Co., Arley Cannel	Atherton	12,500	20.11	719.	0.224	1,305	4.80
Garswood Hall Cannel	Wigan	12,750	27.13	1185.7	—	1,000	9.37
" " Semi-Cannel	"	10,700	16.82	617.	—	1,360	4.0
Garswood Coal and Iron Co., C. F. Clark, Esq.	"	10,620	22.00	801.05	0.878	1,370	6.87
Garswood Coal and Iron Co.	"	9,975	18.77	641.96	—	1,440	23.65
Glendon Iron Works, Napperley	Leicester	9,400	22.06	720.	2,963	1,170	19.47
" " " Dunsdale	"	9,600	20.25	666.51	0.284	1,336	15.42
Haigh, John, and Sons, No. 1	Gildersome	11,500	17.27	743.57	—	1,340	6.25
" " No. 2	Sheffield	10,800	16.57	618.	—	1,348	6.30
Hazelwood Coal Co, Mold Coed Talon Cannel	Mold	14,200	27.38	1332.44	0.540	927	3.45
Hicbibi Colliery, Ellerbeck Cannel	Wigan	11,650	19.43	776.09	—	1,340	5.25
Hindley Field, Wigan, 4 ft., Cannel	"	12,800	23.25	1027.	—	1,053	7.40
Higson, J. and P., Dukinfield Cannel	Dukinfield	11,850	24.	973.66	0.354	1,276	7.0
Howley Park	Batley	11,400	26.	1016.23	0.436	1,310	8.65
Ince Hall, Wigan Cannel	Wigan	12,780	22.35	979.	—	1,411	4.44
" " "	"	12,825	23.34	1027.83	0.888	1,420	4.38
Lambro Moor, No. 1	"	13,250	21.82	1134.08	0.646	1,200	4.20
" " No. 2	"	11,550	17.08	688.08	0.298	1,368	11.72
Lawton Colliery, Lawton Cannel	Stoke-on-Trent	8,000	22.	609.	—	—	—
Little Heaton, Cannel	St. Helens	13,300	16.50	752.40	—	1,413	4.88
Lockwood, S.	Yorkshire	11,600	25.	994.	1.456	1,330	12.05
Midland Coal Co.	Nottingham	11,425	17.75	695.3	1.	1,465	13.3
Moss Hall, 4 ft.	Wigan	10,600	22.28	831.34	0.542	1,300	12.92
" "	"	13 260	27.22	1237.5	0.457	1,015	6.80
Mostyn Cannel	Flint	10,650	16.50	602.5	—	1,413	4.88
Netherseal Cannel	Burton-on-Trent	12,400	28.96	1231.14	0.436	1,017	28.27
New South Wales Cannel	—	15,300	38.43	2126.	—	818	71.
Nunnery Colliery Cannel	Sheffield	12,750	18.14	793.	2.32	1,336	10.
Old Hall Cannel	St. Helens	11,200	23.	883.20	1.103	1,250	5.20
Ormiston, J., Flint Cannel	Flint	13,000	21.79	979.27	0.371	1,245	12.8
Pearson and Knowles, Wigan Cannel	Wigan	11,870	22.78	927.08	—	1,415	4.37

Digitized by Google

Name of Cannel.	District.	Gas per ton. Cubic Feet.	Illuminating Power. Candles.	Value of Gas per ton of Cannel in lbs. of Sperm.	Sulphur in Cannel. Per cent.	Coke per ton.	Ash in Coke. Per cent.
Rochers Cannel	Ashton	11,800	24.15	977.	0.198	1,273	13.12
Rose Bridge, Wigan Cannel	Wigan	11,125	22.63	863.	0.241	1,414	5.
Roscoe and Lord, Mountain Mine Cannel	Farnworth	11,850	16.	605.	—	1,416	0.65
Royal Colliery, Wigan Cannel	Wigan	11,675	20.56	823.	—	1,388	5.22
Sankey Brook Colliery, Cannel in band of coal	St. Helens	10,300	22.00	777.	—	1,180	7.50
Scott Lane Colliery, Wigan Cannel	Wigan	11,980	22.80	936.	—	1,411	4.60
Sheepbridge Coal and Iron Co.	Chesterfield	9,750	21.30	712.	0.386	1,370	17.45
Shirland Coal Co., Shirland Cannel	Alfreton	10,600	22.88	831.34	—	1,300	2.95
Silkstone and Haigh Moor Cannel	Allerton	12.325	21.83	897.12	0.912	1,209	6.12
Simpson and Co., Wigan, 4 ft., Cannel	—	12,600	22.80	964.29	—	1,088	5.45
Smethurst, D. H., and Co.—							
3 ft., Seam Tops	Wigan	11,600	21.	835.20	—	1,306	4.50
„ „ Bottoms	„	11,425	20.53	797.33	—	1,337	5.0
Sutton Heath Cannel	St. Helens	12,900	19.15	847.	—	1,411	5.42
„ „ New Pit	„	12,700	22.63	977.54	0.878	1,249	4 50
Thomson, S., Ibstock Cannel	Motherwell	11,500	18.01	710.11	1.246	1,112	15.
Tyne Boghead	Newcastle-on-Tyne	12,850	32.17	1417.32	2.82	1,248	23.05
Wigan Coal and Iron Co.—							
Wigan Cannel	Wigan	11,580	22.73	889.	—	1,400	4.32
Curley „	„	12,600	27.50	1188.	—	1,241	8.00
Smooth Cannel	„	12,100	24.17	1002.57	—	1,388	2.50
Worsley Cannel	Manchester	11,100	19.	719.	1.134	1,439	7.32

Analyses of Coals (*Hunt*).

(1 *Ton Samples*).

Name of Coal.	Cubic Feet of Gas per ton.	Illuminating Power. Candles.	Lbs. of Coke per ton.	Gallons of Tar per ton.	Sp. Gr. of Tar.
Plumbley	10,940	16.63	5 0	10.50	1.212
Derbyshire Silkstone	10,094	16.05	1518	11.00	1.203
Sheepbridge	10,700	14.79	1491	13.00	1.203
Eckington	10,652	16.03	1451	16.00	1.195
Hornthorpe	10,286	16.89	1562	12 75	1.204
Holbrook	10,539	16.89	1536	15.00	1.184
Silverhill Nuts	10,120	16.82	1483	14.50	1.194
Garswood Coal	10,660	17.43	1432	17.00	1.203
Talk o' th' Hill	10,605	14.30	1592	11.62	1.182
Bignall Hill	10,210	13.87	1589	11.75	1.196
Audley	10,810	14.94	1593	11.50	1.214
Norley, Unscreened	9,066	15.56	1536	9.87	1.168

On inspecting these tables it will be seen that the cannel coals, on carbonisation, yield a larger amount of volatile matter, a gas of higher illuminating power, less coke and a larger quantity of ash than the bituminous gas coals. This is strikingly seen in the extreme case of the Boghead cannel, which has been largely distilled for oil-making.

Bituminous coal is never entirely free from iron pyrites, which gives rise, during the process of carbonisation, to sulphuretted hydrogen and other sulphur compounds, the quantity of which is generally supposed to be

Digitized by Google

increased by using the coal in a wet condition. Carbonate of lime frequently accompanies the layers of coal, forming thin bands between the seams, and may often be of service to the gas-maker in diminishing the amount of sulphuretted hydrogen evolved. At the temperature of the gas retort, the carbonic acid is expelled, and becomes partly converted into carbonic oxide by contact with the red-hot coke, while the calcium combines with the sulphur of the sulphuretted hydrogen, forming sulphide of calcium, which remains in the coke, thus relieving the gas of a portion of its sulphur compounds. It has been proposed also, for the same purpose, to mix lime with the coal before its introduction into the retort; the difficulty, however, in the way of its adoption is the consequent deterioration of the coke.

The natural moisture in the coal, which varies from 1 to 14 per cent. in different samples, is a serious obstacle to contend with in gas-making, as to its presence some of the carbonic acid which accompanies the gas must be attributed, and in order to remove this the cost of purification becomes proportionally increased. Aqueous vapour in contact with red-hot carbon becomes converted into carbonic oxide and hydrogen; moreover, the pyrites yields sulphuretted hydrogen much more readily.

It will at once be seen from the foregoing tables, that cannel coal is far superior to all others in the proportion of volatile matter yielded; and, although it does not necessarily follow that the coal which yields the largest amount of gas is the most valuable gas coal, such is generally the case.

The elements composing the coal which we shall have to consider in studying its decomposition by heat are carbon, hydrogen, oxygen, nitrogen and sulphur. The accompanying table exhibits the average proportions in which these elements exist in different varieties of coal.

Composition of Coal.

District.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
Newcastle	82.12	5.31	5.69	1.35	1.24	3.77
Lancashire	77.90	5.32	9.53	1.30	1.44	4.88
Derbyshire	79.68	4.94	10 28	1.41	1.01	2.65
Gloucestershire . . .	78.09	5.17	7.60	1.01	1.76	6.38
Scotch Coals . . .	78.67	5.67	7.22	1.44	1.44	5.59
Welsh „ . . .	80.77	5.15	7.21	0.79	2.13	3.94

The ultimate composition of a coal is not a safe guide in determining its value as a gas-making coal, but it may be said generally that the percentages of oxygen, sulphur, and ash should be low, and that of the hydrogen, after deducting that equivalent to the oxygen present, should not be much below four per cent.

When coal is exposed to the action of air and moisture, oxidation, chiefly of the hydrogen, takes place, the result being an appreciable diminution in the quantity and quality of the gas obtainable from it. Should this oxidation proceed very rapidly, spontaneous combustion is likely to ensue, the tendency to which is increased by the coal being in a finely divided state, or containing much pyrites.

All specimens of fresh coal contain mechanically occluded gas, which can be driven out by slightly heating the coal in a vacuum. The quantity of this gas varies very much, and is generally greater with the more dense varieties, probably owing to their retaining the gas for a longer period after removal from the mine.

The composition of the occluded gas varies with the nature of the coal; the

Digitized by Google

older coals containing methane, carbonic acid, and nitrogen, with traces of oxygen. Cannel coal, besides the gases just mentioned, evolves considerable quantities of some of the lower members of the methane series of hydrocarbons, principally ethane, C_2H_6, and propane, C_3H_8.

CHAPTER IV.

Carbonisation of Coal.

When coal is heated in closed vessels, the following action takes place:—A carbonaceous residue (coke) remains in the vessel, whilst certain volatile products escape; a portion of the latter, on cooling, is condensed into tar and an aqueous fluid, the remainder being a mixture of gases, with a considerable proportion of the volatile vapours of the different carbon compounds, the greater part of which have been condensed with the tar. The accompanying scheme will give at one view the nature of the products resulting from this process.

Products of the Carbonisation of Coal.

- **Fixed residue.** — Coke, consisting of carbon, with small quantities of hydrogen, sulphur, nitrogen, and ash.
- **Volatile matter**
  - **Liquids separated by condensation**
    - **Tar, separable by distillation into:** First runnings, Light oils, Carbolic oils, Creosote oils, Anthracene oils, Pitch.
      - from which are obtained: Benzene, Toluene, Xylene, Naphthalene, Anthracene, Phenol, &c.
    - **Ammoniacal liquor:** Water, containing in solution— Carbonate, Carbamate, Sulphide, Sulphite, Thiosulphate, Sulphate, Chloride, Cyanide, Sulphocyanide, of ammonium.
  - **Gases and vapours**
    - **Impurities separated by purifying plant:** Ammonia, Carbonic acid, Sulphuretted hydrogen, Cyanogen, Carbon bisulphide.
    - **Purified gas:**
      - Hydrogen,
      - Methane and its homologues, C_nH_{2n+2} — Saturated hydrocarbons.
      - Ethylene „ C_nH_{2n}
      - Acetylene „ C_nH_{2n-2}
      - Benzene „ C_nH_{2n-6}
      - Naphthalene $C_{10}H_8$

        — Unsaturated hydrocarbons absorbed by bromine or fuming sulphuric acid.
      - Carbonic oxide,
      - Nitrogen,
      - Water vapour,
      - Traces of— Oxygen, Carbon bisulphide, and other sulphur compounds.

Digitized by Google

At a temperature of 100° C. (212° F.), a small quantity of gas is evolved from coal, but the decomposition is slight until it approaches a red-heat. At 400° C (752° F.), coal can be completely carbonised, the product however being principally liquid. The gas produced is of high illuminating power, but the quantity is small. The hydrocarbons in the gas belong to the methane and ethylene series, but acetylene and benzene are absent, as is also hydrogen. As the temperature of carbonisation is raised, so the volume of gas produced becomes greater, whilst the quantity of liquid product becomes less and its density greater.

It must not, however, be concluded that the immediate products of the carbonisation of the coal are different, for it is certain that the portion of coal actually undergoing decomposition cannot be at a very high temperature, as the heat absorbed in decomposing the coal and volatilising the hydrocarbons would prevent the attainment of a very high temperature. Probably this decomposing portion of the coal is at a temperature of about 400° C (752° F.).

The different products obtained at higher temperatures are the result of the further decomposition of the primary products of the carbonisation. As these gases pass through the surrounding mass of incandescent coke and along the heated upper portion of the retort, they decompose in various ways, producing other hydrocarbons and free hydrogen, and depositing carbon on the walls of the retort and in the pores of the coke.

The action of heat on hydrocarbons results in the gradual separation of the hydrogen from the carbon. By long-continued exposure to a high temperature this separation can be made nearly complete; but under ordinary conditions intermediate products are formed, a portion only of the hydrogen and carbon being separated in the free state.

The simplest decomposition results in the production of one other hydrocarbon and free hydrogen, as for instance:—

$$\underset{\text{Methane.}}{2CH_4} = \underset{\text{Acetylene.}}{C_2H_2} + 3H_2.$$

The acetylene thus produced is partly polymerised, the most abundant product being benzene:

$$\underset{\text{Acetylene.}}{3C_2H_2} = \underset{\text{Benzene.}}{C_6H_6}.$$

The primary action of heat on ethylene is probably that represented by the equation:

$$3C_2H_4 = 2C_2H_2 + 2CH_4.$$

By the decomposition of toluene, which is a homologue of benzene, naphthalene is produced:

$$\underset{\text{Toluene.}}{4C_7H_8} = \underset{\text{Naphthalene.}}{C_{10}H_8} + 3C_6H_6 + 3H_2.$$

Or, by the simultaneous decomposition of two hydrocarbons, a third may be produced, as:

$$2C_2H_4 + C_6H_6 = C_{10}H_8 + 3H_2.$$

It is impossible, however, to represent, by an equation, the numerous changes which occur on subjecting even one hydrocarbon to the action of heat.

The heavy hydrocarbons like naphthalene are in their turn decomposed with separation of hydrogen and formation of others which are no longer found in the gaseous products of the carbonisation.

As already observed, the hydrocarbons produced by the use of a comparatively low temperature are mostly paraffins (hydrocarbons of the methane series), with some olefines. At a higher temperature the paraffins, except

Digitized by Google

methane, disappear, and are replaced by olefines—ethylene, propylene, and butylene. At a still higher temperature acetylene appears, accompanied by benzene C_6H_6. These are followed by naphthalene $C_{10}H_8$, chrysene, pyrene, diphenyl, &c.

The simplest hydrocarbons of each series, methane, ethylene, acetylene, and benzene, resist the action of heat better than their higher homologues. They are also to some extent reproduced by the subsequent decomposition of other hydrocarbons.

At the commencement of the carbonisation of a charge of coal, when the exterior portion of the mass is undergoing decomposition, the hydrocarbons produced, not having to pass through or over incandescent coke, escape from the retort with comparatively little change, the illuminating power of the gas is high, and it contains but little of the more highly condensed hydrocarbons. As the carbonisation progresses, however, the exterior portion of the mass becomes converted into coke, and its temperature rises and approximates to that of the retort itself, so that the gases produced in the interior of the mass have to pass through a gradually increasing thickness of incandescent coke; consequently the decomposition of the hydrocarbons becomes more and more complete, until finally little but hydrogen, with some methane, is produced.

After the bulk of the gas has been driven off from the coal, it still continues to give off hydrogen for some time, adding to the volume of the gas produced, but lowering its illuminating power. Moreover, as the heat penetrates further and further towards the centre of the mass of coal, the amount undergoing decomposition at any one time continually decreases, so that the volume of gas given off gradually becomes less; this effect is increased by the low conducting power for heat of the surrounding coke.

Methane or marsh gas, CH_4, contains 75 parts of carbon and 25 parts of hydrogen; ethylene or olefiant gas, C_2H_4, contains 85.7 parts of carbon and 14.3 parts of hydrogen; the former is practically valueless as an illuminant, whilst the latter is one of the most important gaseous constituents of nearly all illuminating gases. Coal-gas contains, in addition to hydrocarbons which are gaseous under the ordinary temperature and pressure, the vapours of various solid and liquid hydrocarbons, most of which, however, are condensed in the tar deposited in those portions of the apparatus which are nearest the retorts. Although these hydrocarbons constitute a very small proportion by volume of the gas, nevertheless they contribute largely to its illuminating power, in consequence of the high percentage of carbon which they contain, and of the great weight of their molecules.

In the subjoined tables (by L. T. Wright) is given the effect of temperature on the products of the carbonisation of coal.

TABLE I.

Showing the effect of an Increasing Temperature on the Gas produced from the same Coal.

No.	Gas per Ton of Coals.	Illuminating Power.	Candles per Ton of Coal.
	Cubic feet.	Candles.	
1	8,250	20.50	33.950
2	9,693	17.80	34.510
3	10,821	16.75	36.140
4	12,006	15.60	37.460

It will be seen that the higher the temperature employed in carbonising,

Digitized by Google

up to a certain point, the greater the value of the gas produced, a result no doubt largely due to a portion of the tar being gasified.*

TABLE III.

	Time after Commencement of Carbonisation.			
	10 min.	1h. 30min.	3h. 25min.	5h. 35min.
Hydrogen	20.10	38.33	52.68	67.12
Methane	57.38	44.03	33.54	22.58
Hydrocarbons	10.62	5.98	3.04	1.79
Carbonic Oxide	6.19	5.68	6.21	6.12
„ Acid	2.21	2.09	1.49	1.50
Sulphuretted Hydrogen	1.30	1.42	0.49	0.11
Nitrogen	2.20	2.47	2.55	0.78
	100.00	100.00	100.00	100.00
Carbon density of Hydrocarbons	2.86	3.11	3.38	2.29

From Table III. it will be seen that the proportion of hydrogen continually increases, whilst that of the methane and other hydrocarbons continually decreases. The carbon density of the hydrocarbons, that is, the number of atoms of carbon in one volume of gas, rises at first, but falls towards the end of the process; this is doubtless due to the fact that the olefines, &c., present in the early stages of the carbonisation are later on decomposed with formation of benzene, naphthalene, &c. The fall in the carbon density at the end of the carbonisation may be due to the decomposition of benzene, &c., with formation of acetylene, one of the most stable of all hydrocarbons at high temperatures, and also to the polymerisation of benzene, &c., into heavy hydrocarbons which condense with the tar.

TABLE IV.

Gas made per Ton.	Sp. gr. of Tar at 15.5° C.	Ammon. Water.	Crude Naphtha.	Light Oil.	Creosote.	Anthracene Oil.	Pitch.
6,600	1.086	1.20	9.17	10.50	26.45	20.32	28.89
7,200	1.102	1.03	9.05	7.46	25.83	15.57	33.80
8,900	1.140	1.04	3.73	4.47	27.29	18.13	41.80
10,162	1.154	1.05	3.45	2.59	27.23	13.77	47.67
11,700	1.206	0.383	0.395	0.657	19.44	12.28	64.08

* Upon further increase in the temperature of carbonisation, a decrease in the value of the gas made per ton occurs. This is shown by the following experiments—

TABLE II.

Temperature.	Gas per Ton.	Illuminating Power.	Candles per Ton.
Degrees Fahr.	Cubic Feet.	Candles.	
1400	9,955	18.36	56.585
1520	11,179	18.00	40.244
1600	12,077	17.79	42.969
1740	12,915	16.32	42.255
1835	14,149	14.28	40.409

The Construction of Gas Works, by C. Hunt. "Proc. Inst. Civil Engineers," vol. cxvii., 1894, p. 212.

Digitized by Google

From Table IV. we see that the higher the temperature employed, the thicker the tar; there is also an enormous diminution in the quantity of light oils obtained and an increase in the quantity of pitch, which, with high temperatures, contains a very much greater quantity of free carbon. The higher the temperature employed in carbonisation, the larger the amount of impurities, carbonic acid, sulphuretted hydrogen, and carbon bisulphide in the gas. The following table shows the effect of increasing temperature on the sulphur compounds other than sulphuretted hydrogen:

TABLE V.

No.	Gas made per Ton.	Sulphur other than SH_2.
	Cubic feet.	Grains per 100 cubic feet.
1	6,896	13.91
2	8,370	19.16
3	9,431	26.75
4	10,772	36.93
5	11,620	44.17

The carbon in coal amounts generally to about 80 per cent. of the whole, or rather less in the case of cannel; the proportions in which it is found in the various products of its carbonisation is somewhat as shown in the following table.

One ton of coal containing about 80 per cent. carbon gives:

Carbon in gaseous hydrocarbons . . .	150	pounds.
„ carbonic oxide and acid . . .	30	„
„ tar	140	„
„ coke	1480	
	1800	„

A good gas coal will yield about two-thirds of its weight of coke, equal to 85 per cent. of the carbon. Cannel gives a smaller amount, which, moreover, varies greatly with different varieties. Boghead cannel, when carbonised, leaves only 30 per cent. of residue, of which quite two-thirds is mineral matter.

The hydrogen of the coal is almost entirely driven off during the carbonisation; about half of it is in the form of methane and other hydrocarbons, the rest being in the free state or combined with oxygen in the form of water. Comparatively small quantities are found as sulphuretted hydrogen, ammonia, and hydrocyanic acid.

The oxygen combines with the carbon, forming carbonic oxide and carbonic acid. A portion of the oxygen is also found in the tar as a constituent of phenol, cresol, &c.

Free oxygen is generally present in coal-gas, but is due to the accidental admission of air during the charging of the retorts, &c.

Nitrogen though seldom exceeding 1.5 per cent. of the coal, is an important element, as it is the source of the ammonia, one of the most valuable bye-products obtained in the manufacture of coal-gas. The proportion in which it is found in the products of carbonisation is shown in the following results of experiments by Foster and by Guéguen.

Digitized by Google

After Carbonisation.	Foster.	Guéguen.	
		1.	2.
Nitrogen as Ammonia . .	14.50	19 0	34.0
„ Cyanogen . .	1.56	29.0	27.0
„ unaccounted for .	34.04	—	—
„ in the coke . .	49.90	52.0	39.0
	100.00	100.00	100.00

When coal is carbonised at a low red-heat, little or no ammonia is obtained; the nitrogen volatilised being found in the tar in the form of various organic bases. The quantity of ammonia obtained increases with the temperature employed up to a certain point, beyond which the ammonia begins to decompose, partly into its elements, and partly in contact with the red-hot coke, with formation of hydrocyanic acid: $NH_3 + C = HCN + H_2$. It is uncertain whether any cyanogen compounds are directly produced in the carbonisation of coal, but it is a curious fact that the amount of cyanogen obtained on the Continent is as a rule much higher than that obtained in this country; this is strikingly seen in the analyses given above, and is probably due to the employment there of higher temperatures in carbonising. As bearing on this subject, it may be mentioned that experiments made at the Windsor Street Gas Works, Birmingham, have shown that with the same coal, an increase in the temperature of carbonisation of about 56° C. (100° F.) was sufficient to more than double the amount of cyanogen produced. Whatever temperature is employed, a large proportion of the nitrogen always remains in the coke; some portion of this may be driven off by injecting steam into the coke, but it seems impossible to obtain the whole of the nitrogen as ammonia, except by gasifying the carbon at the same time.

Coal-gas frequently contains a large quantity of free nitrogen, but this cannot all be derived from the coal. If the quantity of nitrogen unaccounted for by Foster, 34.04 per cent., be taken as all present in the gas (though a quantity of it is contained in the tar), it would amount to less than 2 per cent. When coal-gas contains any large quantity of nitrogen, it is undoubtedly due to the admission of air.

Sulphur is the most important impurity of coal, and is present probably in two forms, as a sulphide of iron, and as an organic constituent of the coal. In the former state, it occurs as bisulphide, FeS_2 (cubical iron pyrites, and marcasite); in some coals, however, the proportion of iron to sulphur is such as would form monosulphide of iron, whilst in others again there is an excess of sulphur over that required to form bisulphide, so that in this case, some of the sulphur must be in combination with carbon. Some lignites and mineral resins give off organic sulphides, such as allyl sulphide, when gently heated.

During the carbonisation, the sulphur actually combined with carbon and hydrogen is given off, mostly as sulphuretted hydrogen, but a small quantity also in the form of organic sulphur compounds, of which thiophen is the only one yet identified. At low temperatures, but little of the sulphur of the pyrites finds its way into the gas, but at the temperatures usually employed in gas-making the pyrites is decomposed, the decomposition taking place in two stages. A portion of the sulphur is driven off in the free state, and, in contact with the incandescent coke, it unites with carbon to form carbon bisulphide, but the greater part of the pyrites is decomposed with formation of ferric oxide and sulphuretted hydrogen. If

Digitized by Google

free oxygen has access to the coal, a portion of the sulphur is oxidised to sulphurous acid, and is found in the condensed gas liquor as sulphite and thiosulphate of ammonium.

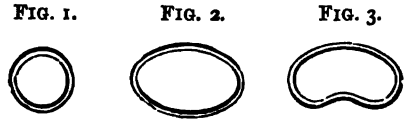
Some coals contain considerable quantities of sodium chloride (common salt) derived from sea water. In the carbonisation of such coals, the chlorine is volatilised as hydrochloric acid, and is condensed in the hydraulic main in combination with ammonia. A portion of the sodium chloride is also volatilised unchanged. This impurity is only important as combining with some of the ammonia which would otherwise have served to remove some of the impurity from the gas; it also necessitates the use of extra lime in the subsequent manufacture of sulphate of ammonia from the liquor.

CHAPTER V.

Gas Retorts.

We will now describe in more detail the several parts of the apparatus used in the manufacture of coal-gas. The vessels used for the destructive distillation or carbonisation of coal are called retorts. Those first employed by Murdoch resembled a deep iron pot, having a lid or cover, and a pipe near the top for carrying away the volatile products. A pyramidal form was afterwards tried, with an outlet at the side near the bottom for extracting the coke, but with this form the heat did not penetrate sufficiently into the body of the coal. Cylindrical retorts of cast-iron, about 7 feet long and 1 foot in diameter, placed at an angle, with openings at top and bottom for charging with coal and withdrawing the coke, were afterwards tried, these in their turn giving way to similar retorts placed horizontally, and having only one charging and discharging aperture, as shown in Fig. 17 (p. 29). These were supported at the back or closed end by a stout peg or projection *v*.

The best form of retort in which to carbonise coal is that by which the coal is distributed in a layer of equal thickness; and at the suggestion of



Sections of Gas Retorts.

Prechtl, the original circular form of retort, Fig. 1, was soon superseded by the elliptical, Fig. 2, which was further improved by bending in the lower surface, Fig. 3.

Flat-bottomed iron retorts, in the shape of a D, a more recent introduction, were for some time more commonly used than any others; the dimensions of these varied in different places, two sizes being chiefly used, the small London D, about 12½ inches wide by 12½ inches deep in the clear, varying in length from 6 to 9 feet; and the York D, from 20 to 30 inches wide, 9 to 14 inches high, and of varying length. Rectangular retorts, with the roof arched, were also sometimes employed. The capacities of these retorts were adapted for charges varying from 120 to 200 lbs., this quantity being worked off in from four to eight hours; thus a retort containing 1½ cwt. of coal would carbonise 6 cwt. in the twenty-four hours.

The method formerly adopted for fixing the lid and ascension-pipe is shown in Figs. 4 and 5. Here the retort has a D form, and the lid extends

Digitized by Google

over the edge of the retort's mouthpiece, being furnished with projecting "lugs" *e e*, by which the lid is supported upon the cottars *d d*. Clay mixed

FIG. 4.

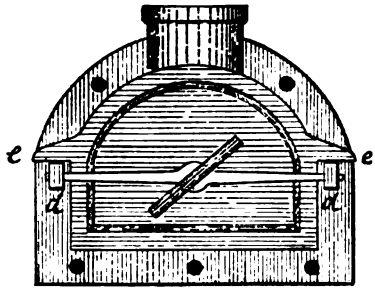
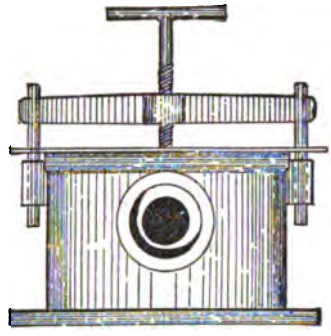


FIG. 5.



Lid of Retort.

with spent lime from the purifiers is employed as cement or luting, and the lid is tightened up by means of the crossbar and screw. An excentric lever, called Holman's fastening, is now used, with Morton's self-sealing lid, the latter being formed with a V-shaped edge, which is pressed by the lever against the faced front of the mouthpiece; a gas-tight joint is thus formed without the use of luting. This arrangement is shown in Figs. 6 and 7, and is applicable to any shape of retort.

FIG. 6.

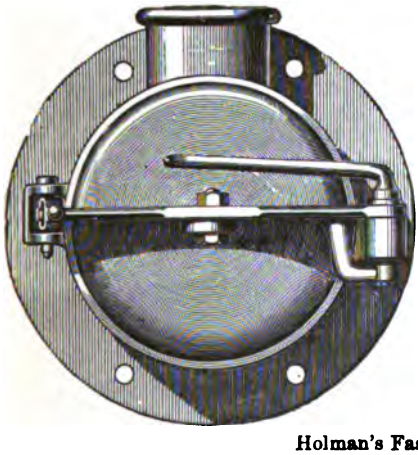
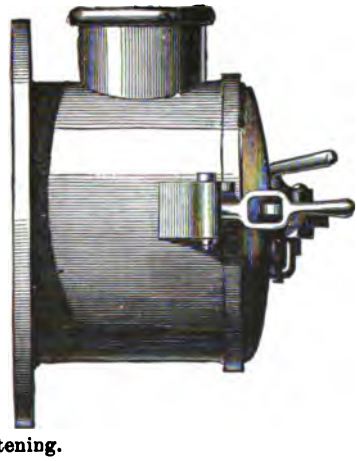


FIG. 7.



Holman's Fastening.

Retorts of double the ordinary length, and of the D shape, with a lid and ascension-pipe at each end, were proposed by Mr. Lowe, and worked or charged at each end alternately, the gas and tar from the fresh charge being allowed to escape over the hot, half-carbonised charge at the other end of the retort. A modification of this reciprocating retort was worked for some time at the Fulham Station of the Imperial Gas Company, where the retorts were set four in an oven or bench, two below and two above; those on the same level being connected with each other by a cross-pipe furnished with a valve, so that the two retorts formed only one distilling vessel when the valve was open, but could be worked separately by closing the valve.

These long retorts are now generally used in all large gasworks, but the drawing and charging are performed at each end simultaneously.

Digitized by Google

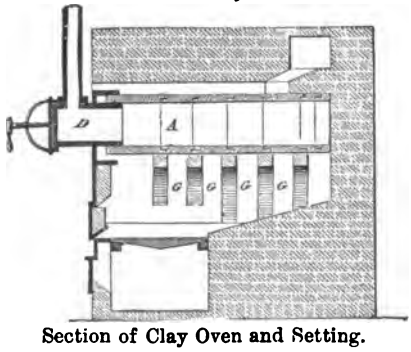
Brunton employed for many years, at West Bromwich, an iron retort in the form of a section of a cone, the smaller end being 15 inches in diameter, and the larger 21 inches; the upper surface being placed horizontally in the furnace, an inclination of six inches was obtained on the lower, the object of which was to afford a more ready discharge of the coke, and allow for the increase in bulk of the coal on carbonisation. An ascension-pipe and also a discharge-pipe opening below the surface of water were attached to the lower wide end of the retort, where was also a door for inspecting the interior. To the front and narrow end, a mouthpiece was attached into which a hopper discharged about 20 to 28 lbs. of coal every hour, the aperture between the hopper and retort being closed by a slide after the admission of each charge. A piston also worked through a stuffing-box in the mouthpiece in such a manner as to force, by means of a screw, the fresh coal forward into the retort, and at the same time discharge a proportional quantity of the coke at the farther end. The fresh coal was thus carbonised in the front part of the retort, and the gas and tar were obliged to traverse the coke at the remoter parts before arriving at the ascension-pipe. So large a proportion of the tar was thus converted into gas that the inventor of the method stated the ultimate yield of condensable products to be 50 per cent. below that obtained by the ordinary method of working. This idea has recently been revived in a very ingenious manner by Mr. J. Elliot, whose arrangement will be hereafter described.

A totally different method of conducting the continuous carbonisation of coal was that in which an endless chain or web moved by machinery was made to convey the coal slowly through the heated chamber, where it is carbonised. This arrangement, the invention of Clegg, is known as the revolving web retort.

The rapid destruction of iron retorts, in the process of gas manufacture, attributed mainly to the direct action of the furnace gases oxidising and gradually burning away the metal, led Grafton, in the year 1820, to propose and patent the use of clay as a material for their construction. They were first made in the form of a square; but the shape shown in Fig. 8 soon superseded the square, and pieces of this sectional shape, 4 to 5 feet wide and 12 to 18 inches high, were joined together with clay so as to form an oven, or carbonising vessel, of 7 feet in length, and capable of carbonising 7 cwt. of coal in six hours, or five times as much as the small iron D-shaped retorts. Each of these retorts, *A*, fitted with an iron mouthpiece, *D*, was at first placed in a separate furnace, as shown in Fig. 9, supported by the pillars, *G G*, but they are now employed of very different shapes—round, oval, and D-shaped, several together in one bench or furnace, as will be described below. Occasionally, as will be seen, they have been associated with iron retorts, but the latter are now almost entirely superseded.

FIG. 8.

FIG. 9.



Section of Clay Oven and Setting.

The grounds on which clay retorts are preferred to iron depend chiefly on two circumstances:

1. The possibility of carbonisation at a higher temperature, with produc-

Digitized by Google

tion of a larger quantity of gas of equal, or even superior quality, from a given amount of coal.

2. Less prime cost, greater durability, and consequently less outlay for wear and tear.

The larger production of gas in clay retorts is generally admitted, although some of the earlier experimenters differed on this point.

Clay retorts are usually worked at a higher temperature than those made of iron, and the larger quantity of gas produced is generally attributed to the decomposition of a portion of the tar at this higher temperature, which, when iron retorts were used, passed into the condenser.

It is an advantage, under some circumstances, that with iron retorts an exhauster is not required, whereas this is an absolute necessity with clay retorts, as the leakage from these would otherwise be so considerable as to outweigh all other considerations.

The relative cost of the retorts is most conveniently expressed by their duration, or, if equal sizes be taken, by the quantity of gas they will produce. The duration of iron retorts was estimated by Barlow as equivalent to the production of 700,000 cubic feet of gas; clay retorts of the same size producing as much as 1,800,000 cubic feet of gas, and continuing in uninterrupted action for seventeen months and longer. Much, however, must depend on the quality of the clay, and the care in the manufacture; as this is now well understood, the durability of a clay retort is generally from twenty-four to thirty months constant work.

Clay retorts are generally made by hand, although in some factories machinery is employed. They are built up, or moulded on end, by surrounding a core with clay for about a foot of the height. The superfluous clay, determined by applying a template of the required thickness and shape of the retort, is then cut off with a wire stretched on a frame, and the piece thus shaped is left for a day or two to allow the clay to shrink. This process is repeated as often as necessary to obtain the required length, the surface of the clay being damped before building up a fresh length. Fig. 10 shows a D-shaped moulded retort of the usual kind.

FIG. 10.

D-shaped Clay Retort.

It is claimed for machine-made retorts that not only is their cost less than those made by hand, but their durability also is greater, owing to their superior density.

As against iron retorts, the drawbacks raised to the employment of clay retorts are as follows:

1. The higher temperature necessary for their being worked advantageously involves a greater expenditure of fuel, and the production of a larger proportion of naphthalene.
2. A greater amount of carbonaceous deposit is formed on the interior, being produced by the decomposition of ethylene, &c.; the quality of the illuminating mixture is consequently impaired.
3. The porous nature of the material allows much gas to be lost by leakage.
4. The brittle nature of clay renders it more liable to fracture.

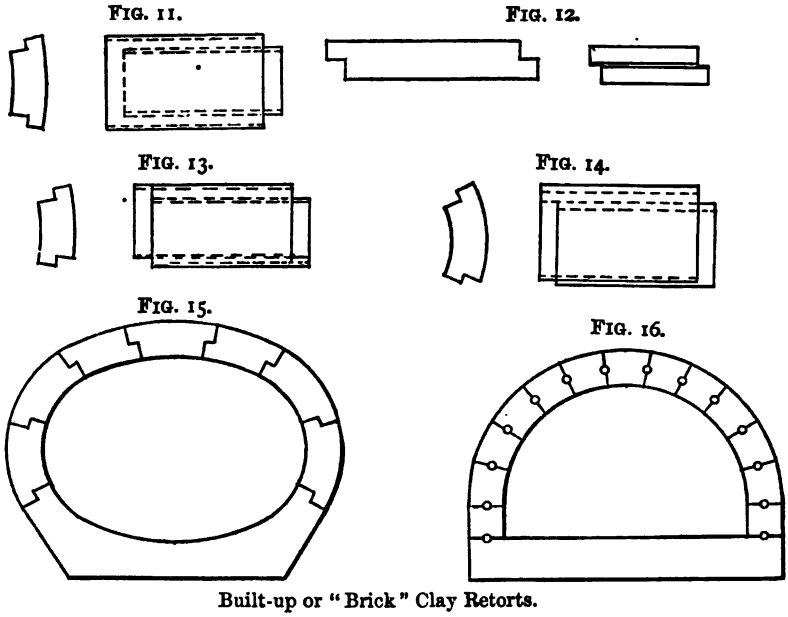
Clay retorts are frequently worked at an incipient white heat; this is of course inadmissible in the case of iron retorts, the best results with which are obtained at a full red-heat. Where ordinary furnaces are employed, the quantity of fuel required to produce an equal quantity of gas has been estimated—

Digitized by Google

For clay retorts, at $3\frac{1}{2}$ cwt. of coke per ton of coal carbonised.
„ iron „ $2\frac{1}{2}$ „ „

This is equivalent for clay retorts to fully one-fourth of the coke produced, and for iron to about one-fifth. Clay retorts, however, afford a larger quantity of gas in a shorter time, and fewer furnaces require to be heated. For this reason, they are found more economical, except where the use of an exhauster is inadmissible.

The second objection has reference rather to the temperature employed than to the material of the retort; and the quantity of carbonaceous deposit is very much influenced by the amount of pressure which the gas must overcome in escaping. Ethylene, when brought into contact with surfaces at a red-heat, is decomposed, depositing carbon, and leaving an equal volume of marsh gas; the higher the temperature, and the longer the gas is exposed to it, the more complete is the decomposition. The deposit of carbon is considerably lessened, as is also the amount of leakage through the pores of the clay, by removing the pressure from the retorts with an



Built-up or "Brick" Clay Retorts.

exhausting apparatus, which pumps out the gas as it is produced, and the use of which is now almost universal.

The porosity of new clay retorts depends greatly on the character of the clay employed in their manufacture, and also on the treatment they have been submitted to in burning. When, however, the pores of the clay become choked with the carbonaceous deposit, leakage is stopped.

The last objection, that is, the liability of clay retorts to fracture, has not much weight, since improved modes of setting and handling them in the furnace have been introduced; and chance cracks may be completely stopped or rendered gas-tight with clay. Moreover, a clay retort admits of being built up in segments, a practice which is frequently followed with advantage to the durability of the retort. Figs. 11, 12, 13, 14, and 15 show an oval-shaped "brick" retort, with the segments of which it is joined. The mouthpiece is made in the usual way, in one piece, and about 2 ft. in

Digitized by Google

length. Fig. 16 shows a D-shaped brick retort, as used at the Old Kent Road Gas Works.

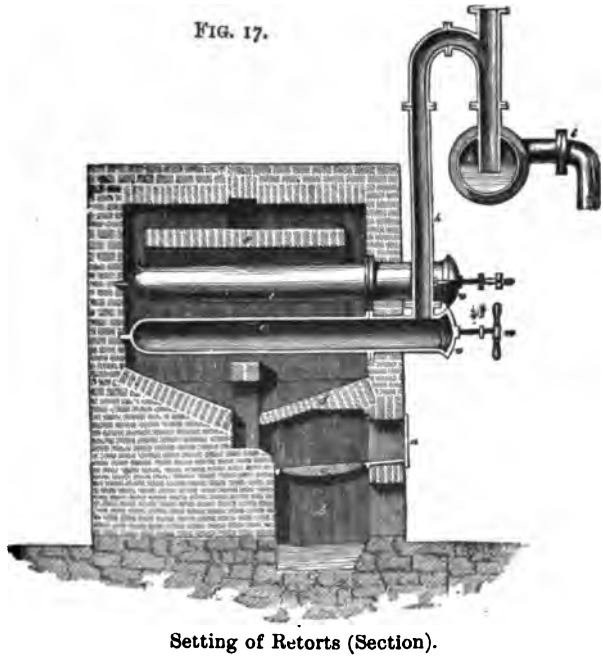
Retorts in the form of an oven, similar to those originally designed by Grafton, 3 ft. 6 in. wide, 8 ft. 6 in. long, and 1 ft. 8 in. high, constructed of fire tiles and bricks, have been used for many years in the west of England, where they were first introduced by Spinney. They are employed separately, or in conjunction with brick retorts, 16 in. in diameter, and of the same length as the ovens. They are adapted for distilling 4½ to 5 cwts. of coal at a time, working off this charge in from six to eight hours. When set separately, about 60 per cent. of the coke produced is consumed for fuel, which is reduced to about 33 per cent. when two retorts are added to the setting, above the oven. These ovens have been known to last for upwards of sixteen years, without being taken down, and at only a small annual expense for repairs. Clift's ovens are similar in design, and equally durable.

CHAPTER VI.

The Furnace, Oven, or Bench.

Fig. 17 shows the arrangement and position in which the retorts were formerly placed in the furnace. Fig. 18 is a front view of the same. Three fires were employed for heating five retorts set in the form of a pyramid. The doors to the fires are shown at *a*, the grate at *c*, and the ashpits at *b*, with a well *e* for water, or used occasionally for drying lime from the purifiers; three arches *d* passed transversely over each fire and divided the flame; *cc* was the large arch overspreading the retorts *rr*, against which the flame was broken, before escaping at the side. The conducting or standpipes dipped into the hydraulic main at *i* in the manner described before. As already seen, the clay retorts first employed were of large size, and set singly, or at most three together; but the amount of fuel required for heating these being very great, smaller retorts were tried, three, five, or seven, being heated by one fire arranged as shown in Figs. 19, 20, and 21. These are front elevations and sections of settings which continue to give very satisfactory results. Fig. 22 shows a front elevation and section of a setting of six retorts used in the United States. The retorts

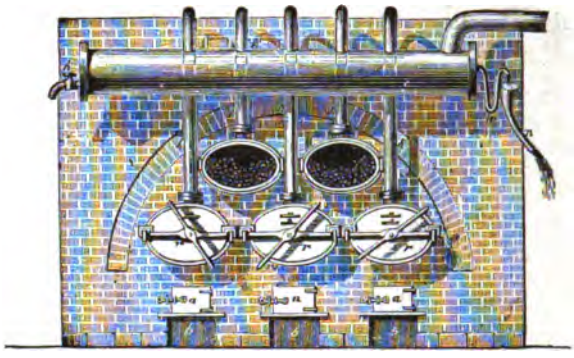
Fig. 17.



Setting of Retorts (Section).

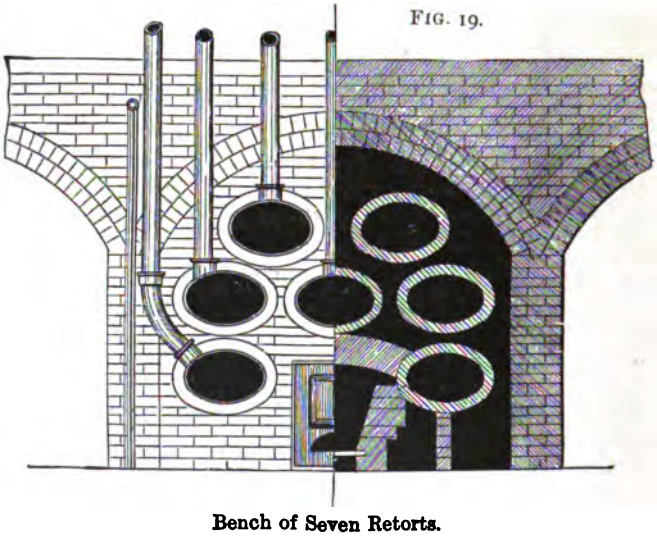
Digitized by Google

FIG. 18.



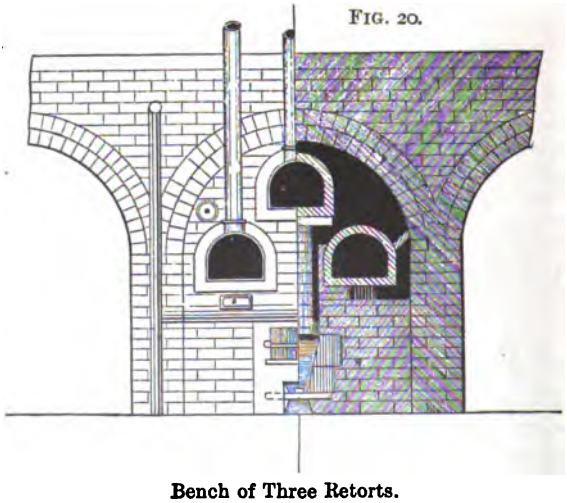
Setting of Retorts (Elevation).

FIG. 19.



Bench of Seven Retorts.

FIG. 20.



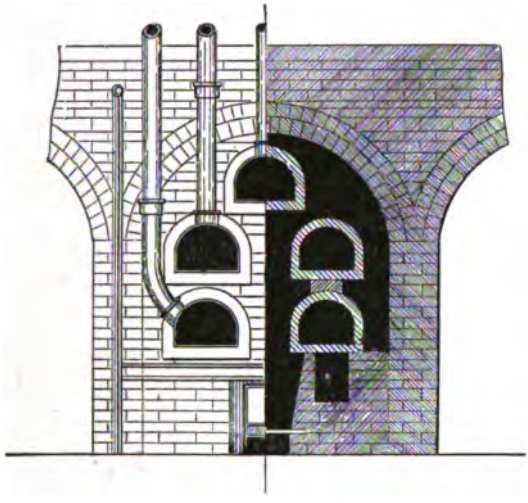
Bench of Three Retorts.

Digitized by Google

are D-shaped, but with the bottoms curved, so as to present a large heated surface to the coals.

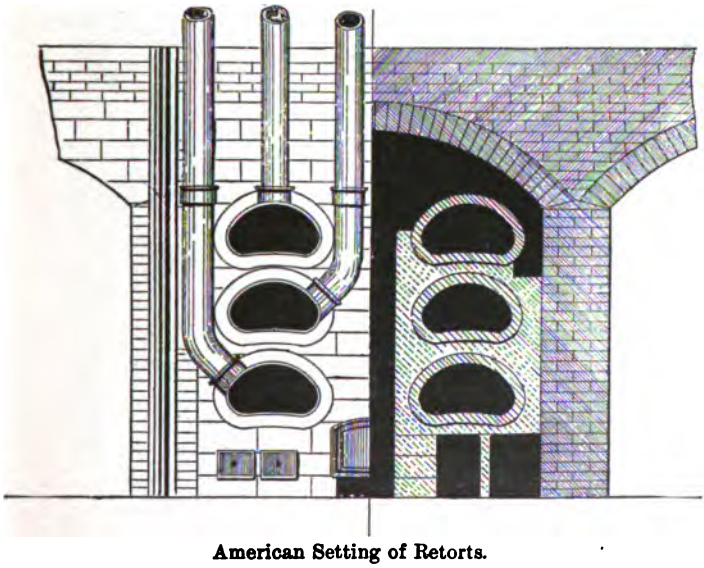
The large proportion of heat, however, which ordinarily passes uselessly into the chimney, induced Mr. Croll to construct furnaces in which both clay and iron retorts could be heated by the same fire, the clay retorts

FIG. 21.



Bench of Five Retorts.

FIG. 22.



American Setting of Retorts.

being arranged immediately above the flame, so as to receive the most intense heat, whilst the waste heat was conducted in a downward direction upon a set of iron retorts.

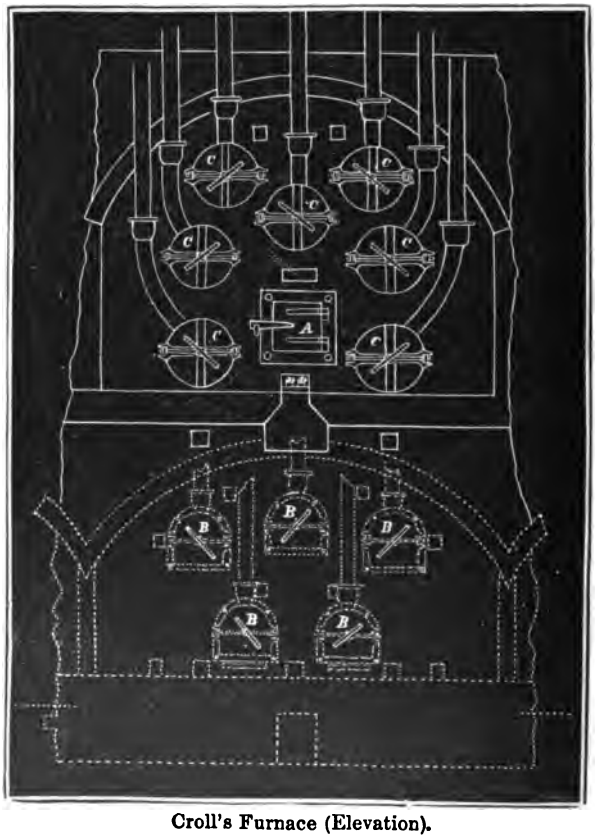
This arrangement is shown in Figs. 23, 24, and 25. Fig. 23 is a front

Digitized by Google

view, Fig. 24 a cross section, and Fig. 25 a longitudinal section of ovens and retorts, as constructed upon Croll's first plan.

The oven was constructed to suit the size of the retorts, and with five iron retorts B B, Fig. 23, three were set towards the top of the oven, each upon three brick pillars, and the two lower ones upon flues 6 inches high, running the whole length of the retorts (compare cross section, Fig. 24), and open at the back. Another oven was placed above, in which seven retorts of fireclay C C C were fixed, five of these being above the furnace or firing A, and one on each side of it. The furnace A is 3 feet long, and 1 foot 6 inches wide, tapering to 7 inches at the level of the two bars D D.

FIG. 23.



Croll's Furnace (Elevation).

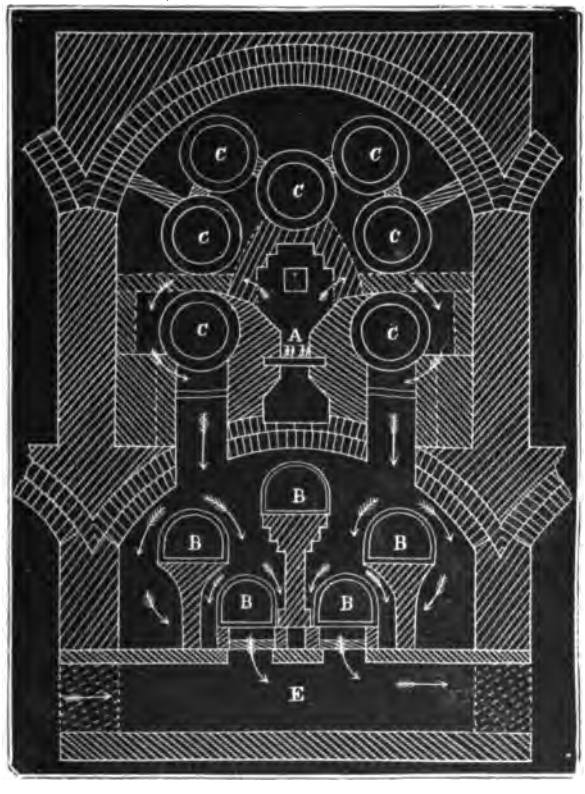
F, Fig. 25, is a trough containing water for cooling the bars, &c. The fuel in this furnace assumes the form of a wedge, the object of which will be afterwards explained. Coke was the fuel used, and it will be seen by referring to the direction of the arrows in the cross section, Fig. 24, that the flame proceeded from the furnace over the two lower clay retorts, and thence (v. longitudinal section, Fig. 25), passed along their bottoms to the further end, where it descended through openings in the arch to the oven below, and came in contact with the front of the upper iron retorts; when they were arranged, as represented in Fig. 25, with their mouths on the opposite side of the retort stack, the heat then traversed obliquely to the bottom of the oven at the back end, where it passed underneath the two lower iron

Digitized by Google

retorts, and was conveyed to their front, descending at last into the main flue E, Fig. 24, running transversely with the settings, and thence to the chimney, which was only about 3 feet above the ridge of the retort house. It was found that the five upper clay retorts were heated quite sufficiently by the heat radiated from the furnace, although the flame was conducted below them to the lower oven. The clay retorts in this arrangement became heated by the most intense part of the flame, which, when it reached the iron retorts below, was so moderated that no casing of clay was needed, nor was the brickwork in contact with the iron fluxed or melted away. The furnace A being wedge-shaped, the fuel sank gradually as it was consumed, thus securing a uniform supply of air.

In the gas-works at Tottenham, where Croll's plans were first carried out,

FIG. 24.



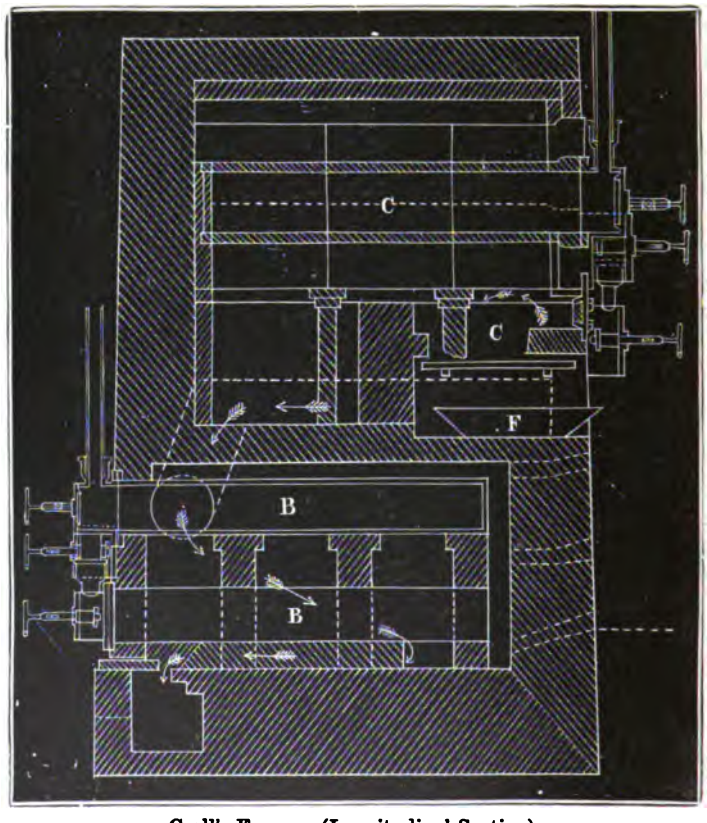
Croll's Furnace (Cross Section).

under the superintendence of Mr. Anderson, the retorts were charged with 260 lbs. of coal, which, in case of necessity, could be raised to 300 lbs., and this was worked off in 4½ hours. The clay retorts were said to last the usual time, but the iron retorts in the lower oven lasted very much longer than ten months, which was the average duration under the old plan; and this was also the case with the brickwork upon which they were supported. A very considerable saving of fuel was also effected by the use of the arrangement described above, only 24 per cent. of the coke produced being consumed in heating the furnace; whilst by setting a greater number of retorts and those of larger dimensions in one furnace, the average consumption of fuel

Digitized by Google

was found to be reduced to from 12 to 15 per cent. of the coke made. In a subsequent modification by Mr. George Anderson, the inconvenience of working the retorts at two different levels was avoided by employing three ovens in combination, the two outer ones containing the clay retorts, and the heat passing from these into the centre oven, in which the iron retorts were placed. Fig. 26 shows an oven constructed upon a combined system of clay and iron retorts, which was successfully adopted by Mr. Lowe in 1844 at the Chartered Gas Works, Brick Lane. A A A are three clay retorts which receive the first heat of the furnace; B B are two iron ones, over which the heat traverses before it reaches the exit flues C C. When

FIG. 25.



Croll's Furnace (Longitudinal Section).

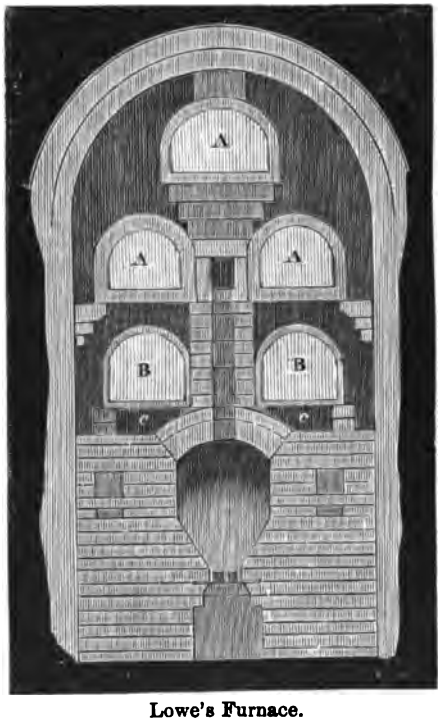
Newcastle coal is used, the consumption of fuel upon this system is stated not to exceed 25 per cent. of the coke produced. The arrangement shown in Fig. 23 (p. 32) was first constructed by Mr. Croll, under licence from Mr. Lowe.

The great importance of fuel economy has during recent years led to an extensive adoption of the regenerative system of gas firing for heating gas retorts, by which other advantages, in the shape of a higher and more even temperature, with increased facility of working, have at the same time been secured. At the Paris Gas Works, the Siemens system, with alternating regenerators, was applied more than twenty years ago, and, with modifications, has since continued to be extensively employed. The retorts used are D-shaped 3 metres (9.8 feet) in length, 0.65 metres (25.6 inches) wide, and

Digitized by Google

0.350 metres (13.8 inches) high, seven or eight being set in one furnace; they are charged every four hours, carbonising 800 kilos. (15¾ cwts.) of coal per retort every twenty-four hours, with a production per mouthpiece of 230 cubic metres (8122 cubic feet). A similar arrangement was tried experimentally at one or two works in this country, without leading to its permanent adoption. In Germany, furnaces in which the process of recuperation is continuous, are largely employed, the systems most in favour, and which may be regarded as typical, being those of Klönne, Schilling, and Liegel. The two first named are alike in so far as the separation of the furnace from the gas flue and generator by a covering or arch, through openings in which the gas passes into the furnace; but they differ materially in the position assigned to the generator, and also in the form and construction of the regenerating arrangement. In the Liegel, there is no such separation of the generator from the furnace, the air for the combustion of the gases being admitted, after passing through the regenerative channels, into the combustion chamber, which is entirely open to the generator, and is separated from the retort furnace by an arch similar to that of an ordinary furnace.

FIG. 26.



Lowe's Furnace.

The Schilling regenerative furnace, as used at Munich, is shown in Figs. 27, 28, 29, 30 and 31, and the results obtained by it are thus summarised in the Journal of Gas Lighting.*

Yield of gas per setting per 24 hours . . .	81,200 cub. ft.
Coal carbonised „ „ „ . . .	7 tons 4 cwts. 42 lbs.
Consumption of coke „ „ . . .	15 cwts. 80 lbs.
(Percentage of ash in coke 14.)	
Yield of gas per mouthpiece per 24 hours . .	10,150 cub. ft.
(Four hour charges; 7 oval retorts 20½″ × 15″ × 9 ft. 9 in.; and one round retort 16″ dia. × 9 ft. 9 in.)	
Yield of gas per ton (Saar coal, with 10 per cent. of Bohemian cannel)	10.940 cub. ft.
Weight of charge	3 cwt.
Consumption of coke as fuel, with 14 per cent. ash, per cent. of coal carbonised . . .	10.9 per cent.

Fig. 27 is a longitudinal vertical section through the generator, retort setting, and regenerative structure complete; Fig. 28 is a transverse section through V, VI; Fig. 29, is a section of the generator through I, II.; Fig. 30 is a sectional plan of the generator through VII, VIII; and Fig. 31 is a section of the same through IX.

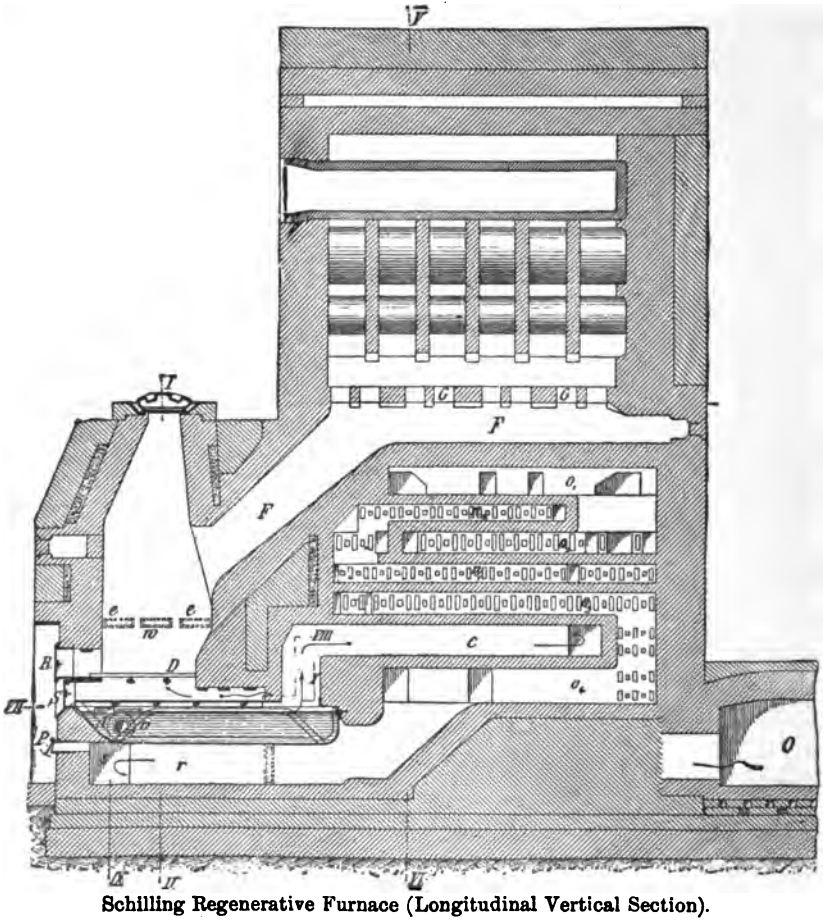
The air for primary combustion enters the generator through an opening *A*, Fig. 30, which is furnished with a damper, and mixes with the steam

* "Journal of Gas Lighting," 1882, l. 1036.

Digitized by Google

rising from the water-pan *B*. The mixture, after passing through the channels c, c_1 and c_2 c_3, where it is warmed by contact with the walls of the adjoining flues containing the spent gases, issues under the grate *D* at the back, and rises into the generator. The generated gases escape through the channel *FF*, Fig. 27, into the furnace, and at *GG* meet the secondary air previously heated in the regenerator. The combustion gases take the course through the setting indicated by the arrows, Fig. 28; leaving the setting at the back end of the bottom flue *x*, Fig. 28, whence they pass into the regenerator.

FIG. 27.



Schilling Regenerative Furnace (Longitudinal Vertical Section).

The spent gases go through the flues o_1, o_2, and o_3, which lie between the air channels n, n_1, n_2, n_3, and n_4, and then pass on through o_4 to the front, underneath the channels which contain the primary mixture of air and steam; passing at *r* underneath the water-pan where the steam is generated, and finally escaping through *S* into the main flue *O*. These flues and channels are so arranged that the air and steam, on their way upwards, move in a contrary direction to the spent gases passing downwards. A rapid exchange of heat between the contiguous flues and channels is promoted by the use of perforated fire-bricks, as shown in Figs. 27 and 28,

Digitized by Google

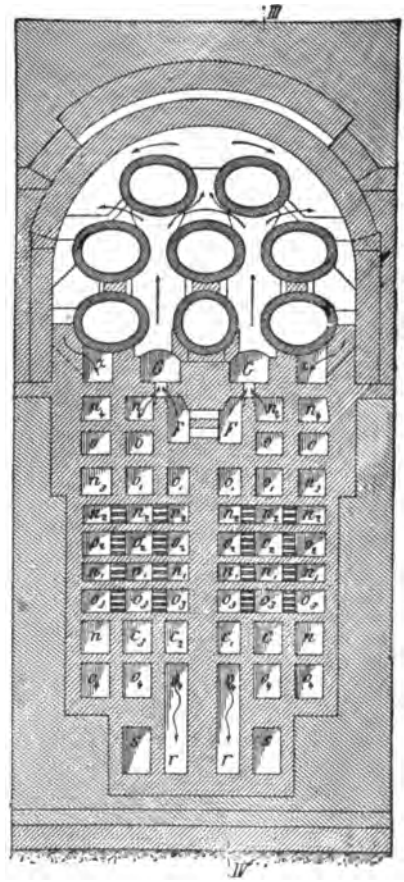
which also add to the stability of the structure. A damper placed after the regenerator, shown by the vertical dotted lines under the water-pan in Fig. 27, enables the difference in the pressure of the gases occupying contiguous channels to be minimised, and thus the liability to leakage is reduced.

The heating surface of the water-pan is sufficient to generate from 1000 to 1300 kilos. (2200 to 2860 lbs.) of steam every twenty-four hours, the production being regulated according to the degree of fusibility of the clinker from any particular kind of coke, by means of a valve *P*, Fig. 27, through which cold air is admitted underneath the pan into the flue *r*; in this way, the temperature may be reduced until the generation of steam reaches the desired average.

The ashes deposited on the grate from the combustion of the coke are removed not oftener than every twenty-four hours, but may remain without inconvenience for thirty-six or even forty-eight hours. The ash space is cleared by introducing through the openings *e e*, Figs. 27 and 29, extra fire-bars, by which the body of fuel in the generator is held up. The doors *R* and *S* in the front of the generator are then removed, and the ashes raked out. Ten minutes suffice for this operation, after which the clearing doors are shut, and the false bars removed, when the generator goes on working as before. The water-pan is replenished by a continuous stream at *U*, Fig. 31. Ovens of this design are not found to be injured by being let down and relighted, the regenerator being so constructed that no interchange or leakage can occur in the flues or channels; the stability of the structure will therefore endure for years without repair.

The average constitution of the gas from the generator, which enters the setting at a temperature of 1150° C., is stated to be as follows:

FIG. 28.



Schilling Regenerative Furnace
(Transverse Section through V, VI).

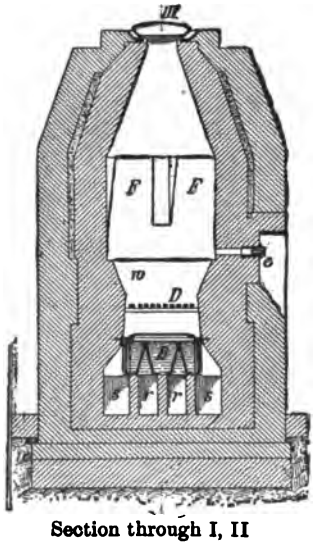
Carbonic acid	8.6 per cent.
Carbonic oxide	20.6 ,,
Hydrogen	15.0 ,,
Nitrogen	55.8 ,,
Volume	100.0

The waste gases leave the setting at about 1400° C. After passing through the flues to o_3, and losing some heat to the secondary air supply, they still register 900° C.; whilst the air, before entering into combination, is raised to 1000° or 1100° C. Continuing downwards the waste gases heat the air in channels *c* to c_3 to about 350° C., and are still at 550° C. when

Digitized by Google

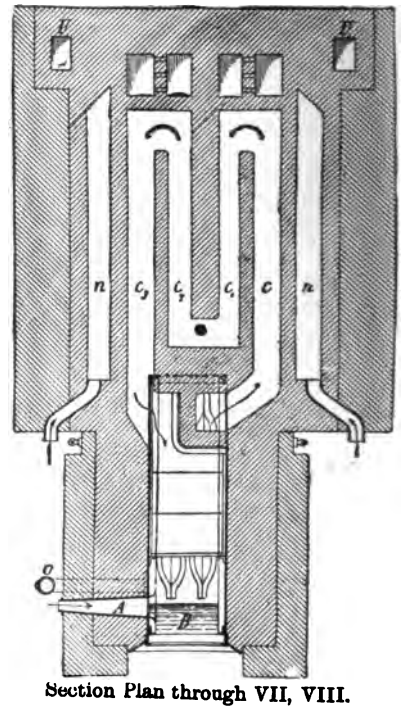
they generate steam from the water-pan. Upon these observations the following conclusions have been based:—If the waste gases escaped from the setting at 1400° C., without doing any further work, this temperature would imply the loss of about 64 per cent. of the heating value of the coke. As, however, these products of combustion are cooled down in the regenerator to 550° C., the loss is reduced to about 25 per cent. The difference represents the gain given back to the setting; about 20 per cent. is restored by the hot secondary air, 6 per cent. is represented by the heated generator air, about 5 per cent. goes in the generation of steam, and the rest is lost through conduction and radiation.

FIG. 29.



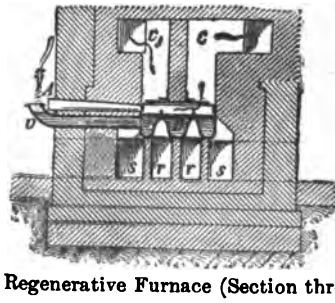
Section through I, II

FIG. 30.



Section Plan through VII, VIII.

FIG. 31.



Schilling Regenerative Furnace (Section through IX).

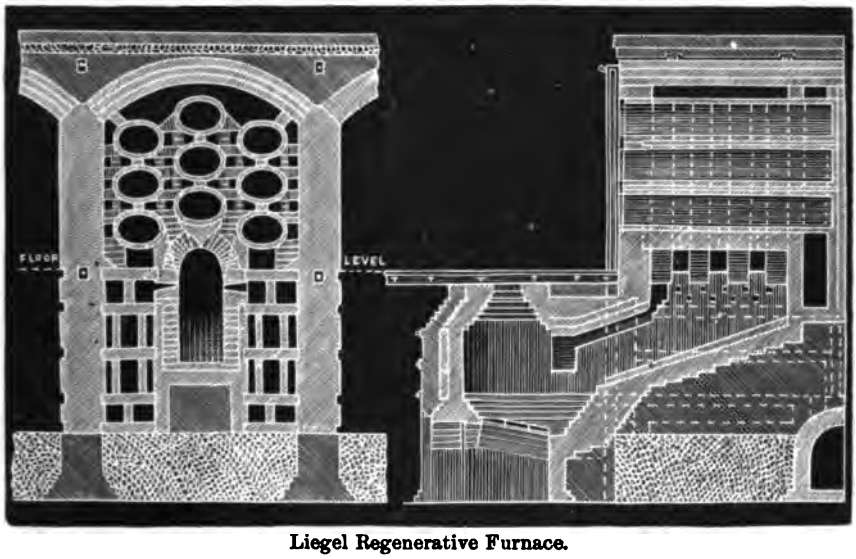
Fig. 33 shows the generator portion of the Liegel arrangement (Fig. 32, the transverse section) in which a contracted opening or slit takes the place of the grate bars more usually employed.

Experiments made by a commission appointed by the German Gas and

Digitized by Google

Water Association to investigate the working of gas generator furnaces of the foregoing types, with and without steam, and under variations of draught, have proved the superiority of the grate, or Schilling generator, when worked with a proper steam supply. This was fixed by the experimenters at from 70 to 80 per cent. of steam to coke, by weight, according to the quality of the coke used.

FIG. 32. FIG. 33.



Liegel Regenerative Furnace.

With coke made from Zwickau coal, the following comparison is made between the "slit" and "grate" generators, working under similar conditions.

1. Slit generator, without steam, 0.066 in. draught, 1113 kilos. (2450 lbs.) of coke per 24 hours.

Carbonic acid	4.5 per cent.
Carbonic oxide	25.7 „
Hydrogen	—
that is	
Carbon gases (CO_2 and CO)	30.2 „
Combustible gases (CO and H_2)	25.7 „

2. Grate generator, with 0.7 kilo. of water (as steam) per kilo. of coke, 1088 kilos. (2390 lbs.) of coke per 24 hours.

Carbonic acid	8.0 per cent.
Carbonic oxide	19.0 „
Hydrogen	12.6 „
that is	
Carbon gases	27.0 „
Combustible gases	31.6 „

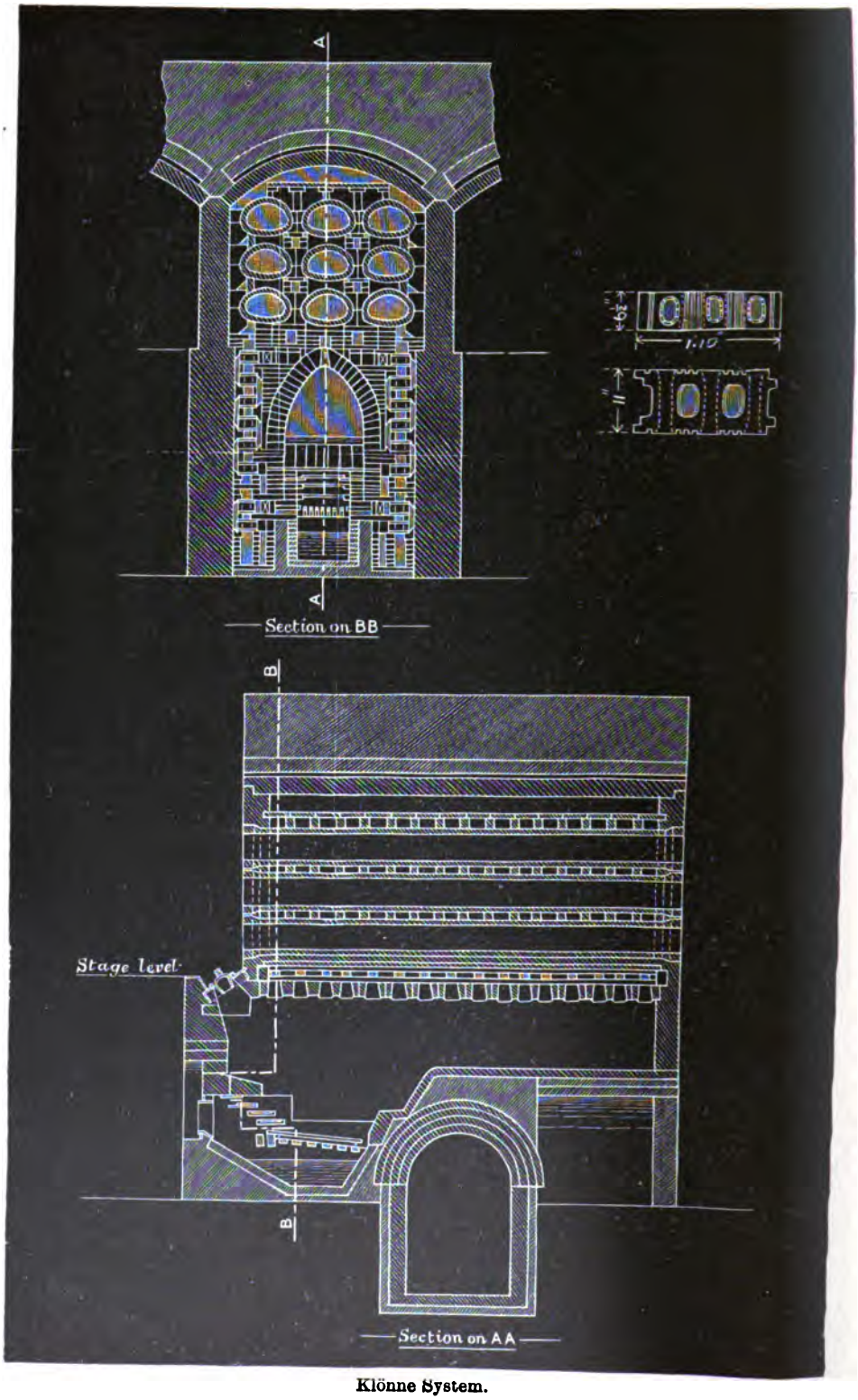
Quantity of coke required for the production of one cubic metre (35.316 cubic feet) of heating gases.

Slit generator, without steam	0.162 kilo. (0.357 lbs.)
Grate „ with „	0.146 kilo. (0.319 lbs.)

With coke made from English coal, the best result was obtained with 072 kilo. of water per kilo. of coke, the total percentage of carbon gases being 29.2, and the percentage of combustible gases 33.2. These proportions of steam were also found most effectual in preventing the formation of clinker.

Digitized by Google

FIG. 34.



Klönne System.

Digitized by Google

At the Wiesbaden Gas Works, where Klönne's furnaces are in operation, the following results are stated to be obtained:—From each retort, 24″ × 14′ by 10 feet long, the production of gas per twenty-four hours is 12,600 cubic feet having a specific gravity of .420.

One ton of coal produces 10,885 cubic feet of gas,

61.8	per cent.	of	coke,
5.0	„	„	breeze,
1.0	„	„	slack,
67.8			

and the quantity of fuel used in the furnaces to heat the retorts is 10.90 per cent. of coke and .95 per cent. of breeze or slack; making 11.85 lbs. by weight in carbonising each 100 lbs. of coal.

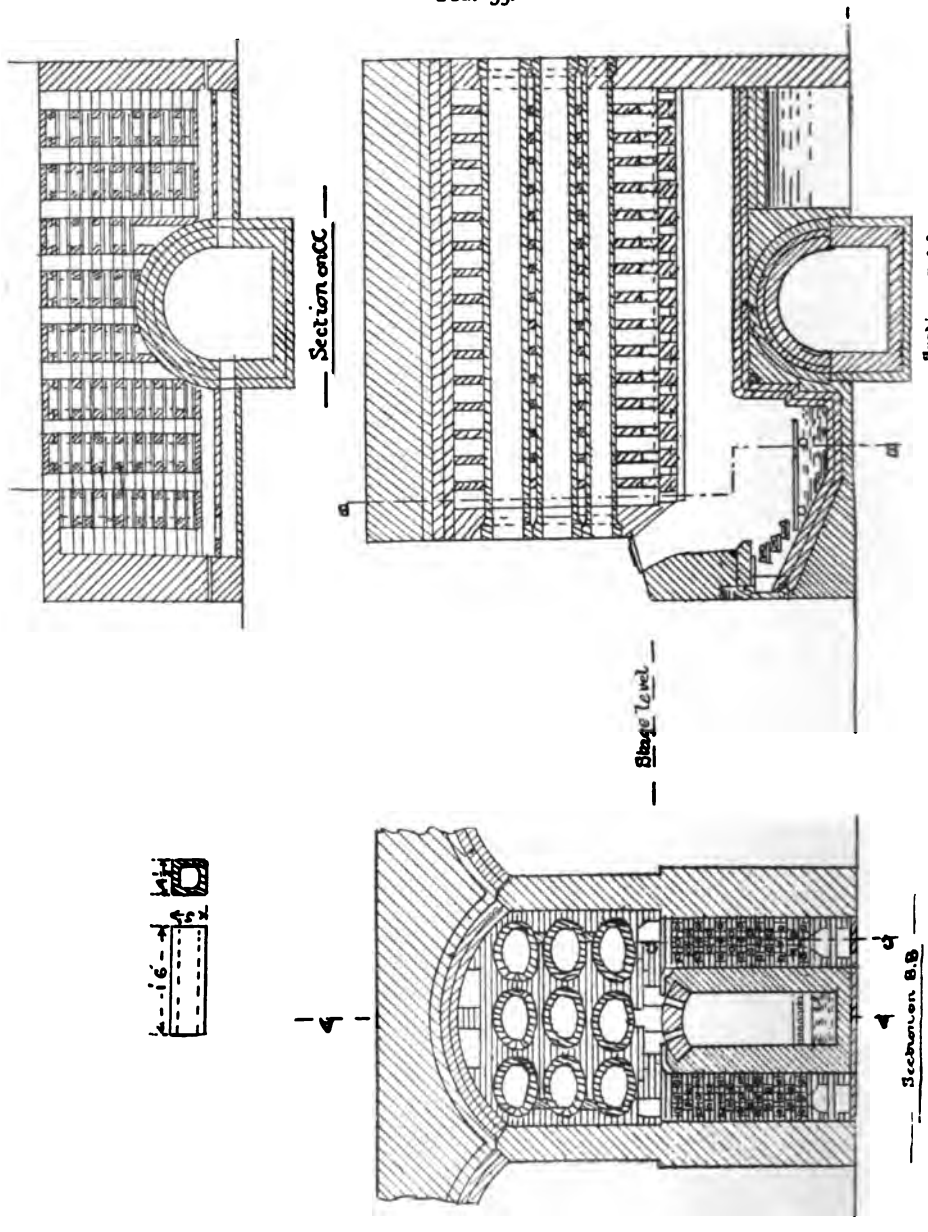
The Klönne system has been employed in England since the year 1881. Fig. 34 shows front elevation and section of the furnace employed at the Birmingham Gas Works, for heating nine oval D-shaped retorts, 22″ × 16″ × 20 feet long, being the first example of so large a retort furnace heated by means of one generator. The generator is placed almost entirely beneath the retort setting, projecting only sufficiently to allow of the red-hot coke being dropped into it when drawn from the retorts. Flat plates of cast iron, 6 inches wide, form a series of steps at the back of the fuel, similar to those of an ordinary Siemens producer, these being kept cool by the constant dripping of water from a pan, placed immediately underneath the projecting ledge of brickwork above the steps; the water being collected in the ashpan below. The fire bars are withdrawn for the removal of clinker and ashes once every twenty-four or forty-eight hours, the fuel being kept up during this operation by false bars inserted between the steps, and supported at the further end of the generator by a set-off in the brickwork. A wide gas flue extends from the generator to the opposite end of the setting, through openings in the arch of which the gas enters the furnace. The regenerator is formed with a series of specially made bricks shown in the cut, which are pierced with openings occurring at right angles to each other, those from top to bottom of the brick being for the passage of the waste gases downwards, whilst through the side openings the air threads its way now to the right and then to the left, until it reaches the furnace, the direction of the current being controlled by alternating courses of rebated bricks. Air is admitted to the generator through side openings, by which it passes through the two lower courses of regenerator bricks, entering the generator just underneath the fire bars. The secondary air is admitted into the regenerator through openings situated a little higher; and these, together with the openings for the admission of the primary air, are provided with sliding doors for the purpose of regulation. The waste gases, which leave the furnace at a temperature of from 1400° to 1600° F., are reduced to about 500° at the outlets of the regenerators; the secondary air being heated in its passage to the furnaces to about 1200°.

Various modifications of this furnace have been brought into use with satisfactory results. It is capable of a very high production of gas per mouthpiece, with great economy of fuel, the consumption varying from 9 to 12 lbs. of coke per 100 lbs. of coal carbonised. At Cheltenham, with these furnaces, the retorts are charged five times in each twenty-four hours with a production per mouthpiece, from 24″ × 14″ retorts, 19 feet in length, of 8297 cubic feet; the production per ton of coals being stated as 10,545 cubic feet.

Hunt's modification of Klönne's furnace is shown in Fig. 35. Instead of the perforated bricks already described, square tubes 4½ × 5 in., and of suitable length, made of fireclay, are employed, the ends of which are

Digitized by Google

FIG. 35.



Digitized by Google

built into cross walls, distanced about 9 in. apart throughout the entire length of the setting. These walls form a series of flues alternately for the waste gases and the air for secondary combustion, the former descending through every other one to the exit flue, and the air rising up the intermediate one on its way to the furnace. The tubes form a connection between the flues, conducting air to air and gas to gas; whilst at the same time they present a thin conducting medium for the passage of the waste heat. Flues built in this way are found to be very little subject to leakage after the furnaces have been several times in use. At Leicester, furnaces of this design are found to produce 8320 cubic feet per mouthpiece where the retorts, which are 22″ × 16″ oval D-shaped, and 22 feet in length, are charged every six hours with 4 cwts. of coal, the production per ton of coal carbonised being stated at 10,400 cubic feet, with an illuminating power of seventeen candles. At a higher temperature, these retorts are made to carbonise five charges of 4 cwts. each per mouthpiece every twenty-four hours, the yield of gas being 10,600 cubic feet per ton and mouthpiece, and the illuminating power about the same as when charged at intervals of six hours; but the tar is somewhat depreciated in quality and is found to thicken, and so cause obstruction in the hydraulic main.

At the Brentford Gas Works, Mr. Frank Morris employs a regenerator also formed with square fireclay pipes, but placed on end so as to form a straight flue from bottom to top. Very good results are obtained by this means, and it may be mentioned, as a proof of the perfect action of the generator, that charging doors are dispensed with, the holes being closed up each time with dust and breeze after the generators have been filled with hot coke from the retorts.

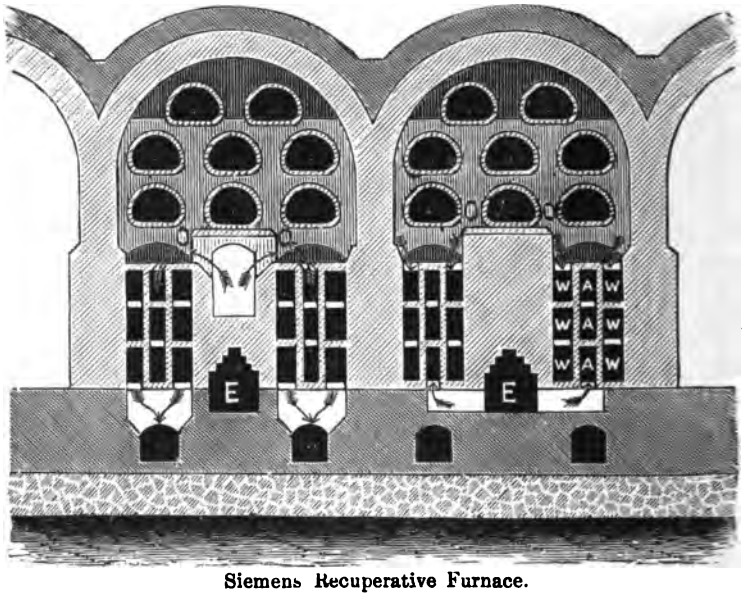
A useful form of regenerative furnace has been adopted by the Gas Light and Coke Company at their Nine Elms station, in which the generator projects about 3 feet from the front of the setting, so as to admit of the hot coke falling from the retorts directly into it. Within the generator is a sloping apron of brickwork, which directs the course of the fuel as it falls, to the centre, where combustion is taking place. The saving of labour by this arrangement is appreciable, there being no necessity to trim back the coke as it falls into the generator. The regenerator is constructed separately from the rest of the brickwork, and is formed of "Ewell bricks," carefully rubbed and built up on edge.

A system of continuous recuperation devised by the late Sir William Siemens is shown in Figs. 36 and 37 (p. 44), illustrating the furnace in use at the Glasgow Gas Works, which is thus described by Mr. W. Foulis, engineer-in-chief to the Glasgow Gas Committee: "The generators are plain cylinders of brickwork without any bars, and having portholes at the bottom to admit air and allow the ash to be withdrawn as shown at P. They are 3 ft. in diameter for single retorts and 7 ft. deep, and are built of 9-inch brickwork enclosed in a malleable iron casing. The object of this casing is to bind the brickwork together, and also to make the producer air-tight so as to prevent air being drawn through the joints of the brickwork. The openings at the bottom of the producer are 16 in. by 11½ in., and are not closed in any way. The producer stands in front of the retort bench, and communicates with it by a flue. A small jet of steam is admitted at each opening in the bottom, which prevents the ash from slagging. The regenerator consists of a series of flues underneath the retort setting. The air enters by an adjustable slit, and passes into the chamber E, where it is partially heated. It then passes through the flues A into the setting. These flues are built of ordinary fire-brick and 3-inch tiles, care being taken to have the joints built close. The flues pass from back to front five times, thus giving altogether 45 ft. length of travel for the air. On each side of the air flues are

Digitized by Google

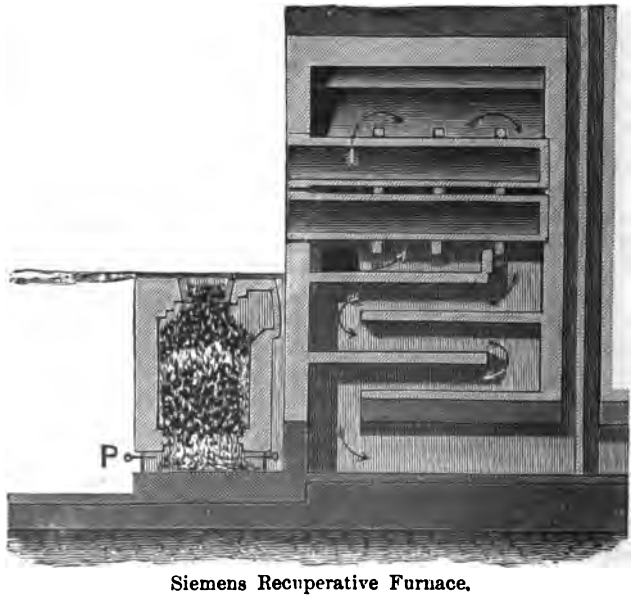
the waste gas flues W; these run parallel to the air flues, and also zigzag from back to front, thus heating the air flue throughout its entire length, but, of course, to a higher temperature as it approaches the setting. The

FIG. 36.



Siemens Recuperative Furnace.

FIG. 37.



Siemens Recuperative Furnace.

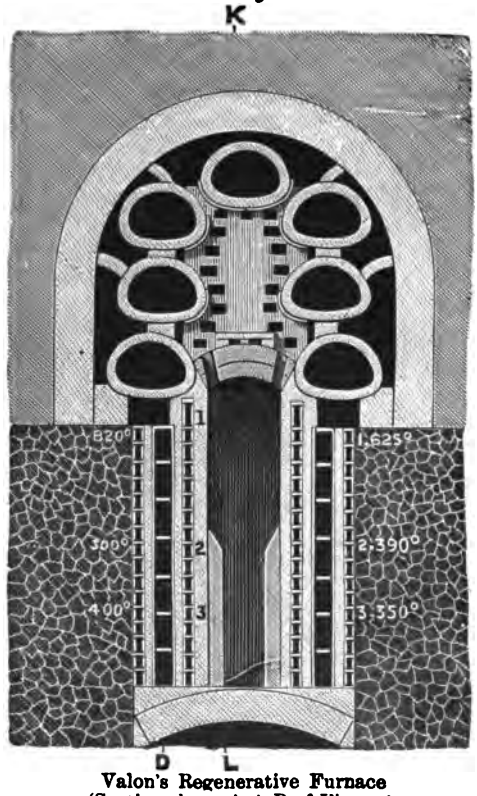
lower portion of the air flue is very little above a black heat, while the top portion is nearly of the same temperature as the setting. The hot air and gas, meeting at the points O O where they enter the setting, create a strong

Digitized by Google

heating flame throughout the entire setting. It is found in practice to be preferable to allow the gas and air to enter by large openings, as by this means a larger flame is produced, thus avoiding very intense local heating.

"The mode of working the furnace is as follows:—Immediately before the retorts are drawn the ash is removed from the bottom holes of the producer. The cover of the producer is taken off, and a sufficient quantity of coke is drawn direct from the retorts to fill it to the top. The cover is then replaced, and little or no attention is required for six hours. To keep the cover air-tight, a luting is used, made of ashes and waste lime ground together to the consistency of mortar; a layer of this, about 2 ins. thick, is placed on the top of the coke, and the cover is bedded down on it. This luting does not shrink or crack, and is a very good non-conductor of heat. When the coke falls away, it leaves it as a hard cake, which completely prevents the ingress of air; and when the producer is opened this cake is knocked away. A very small quantity of steam, admitted at each of the openings at the bottom of the producer, through a nozzle about $\frac{1}{8}$ in. diameter, prevents the ash from slagging; and, except just before they are filled, the bottoms of the producers do not require to be touched—no clinkering, in the ordinary sense, being required."

FIG. 38.



Valon's Regenerative Furnace
(Section through A B of Fig. 39).

The saving of fuel effected by these furnaces over the ordinary furnaces previously employed is stated to be about 45 per cent.—with an increased yield of gas per mouthpiece of about 1500 cubic feet, the production being 8500 cubic feet, as compared with 7000 cubic feet obtained by the old system, a large proportion of cannel coal being employed.

For heating settings of single retorts, usually from 9 to 10 feet long, or of double or "through" retorts fired at each end, regenerative furnaces, designed by Valon,* Isaac Carr, and others, are employed. Valon's arrangement is shown in Figs. 38 and 39. The regenerative portion of the furnace, however, does not differ materially from that of the Glasgow furnace described above. In the latter, the waste gases pass to the chimney through horizontal flues placed on each side of those through which the secondary air supply ascends to the setting. In Valon's furnace the

* See "Transactions of Gas Institute," 1884, p. 93.

Digitized by Google

waste gas flues are placed between the secondary air flues as shown in Fig. 38—the larger flues being used for the waste gases. The temperature of the air flues at the places marked 1, 2 and 3, are given in the figure. It will be noticed that the air flues next to the furnace are at a higher temperature than the outside flues, so possibly this arrangement may act beneficially in reducing the temperature of the furnace walls, and thereby prolonging their duration.

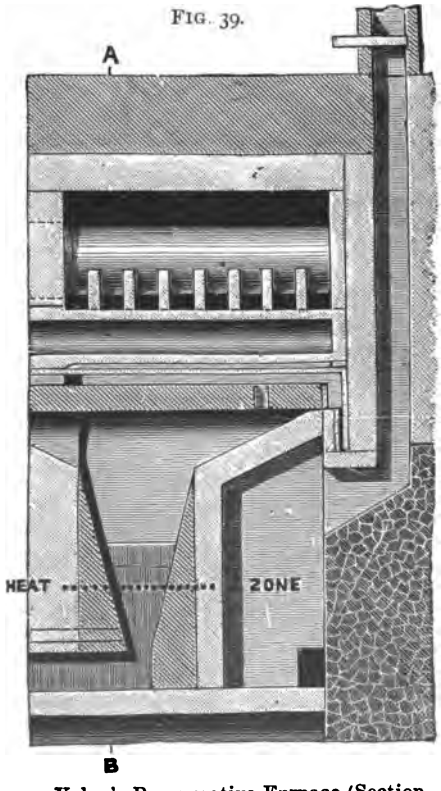
The systems of Valon and Carr do not differ essentially from those previously described, but are stated to secure, at less cost of construction, the principal advantages of gas firing, the saving in fuel varying probably with the extent to which recuperation is effected. Mr. Carpenter, however, has succeeded, at the Vauxhall Road Works, in heating four beds of six retorts each, with one pair of generators, using for the purpose rather less than one-fourth of the coke produced. This is without recuperation, the secondary air being heated to the temperature of combustion in its passage through the furnace.

The advantages of the regenerative system of firing, as applied to the heating of gas retorts, may be summed up as follows:—

1. The maintenance of a higher and more even temperature, resulting in a greater production of gas per mouthpiece.

2. A saving in ground space occupied by the retort-house, resulting from the increased productiveness of the retorts.

FIG. 39.



Valon's Regenerative Furnace (Section through K L of Fig. 38).

3. A saving in labour, the generators requiring less attendance than ordinary furnaces; and in the greater durability of the retorts, owing to the evenness of temperature.

4. A considerable saving in fuel.

Against these advantages may be urged, first, the cost of construction, which on their introduction was more than twice as much as for ordinary furnaces, although now considerably reduced by the various modifications and improvements that have been suggested by experience; and, secondly, a probable diminution in the production of tar and ammonia, resulting from carbonisation at higher temperatures. Where, however, coke is readily saleable, and especially in times of scarcity of fuel, the increased return from it is sufficient to repay the additional outlay in from 12 to 24 months; whilst against a slightly diminished yield of tar and ammonia may be reckoned an increase in the yield of gas per ton of coals carbonised.

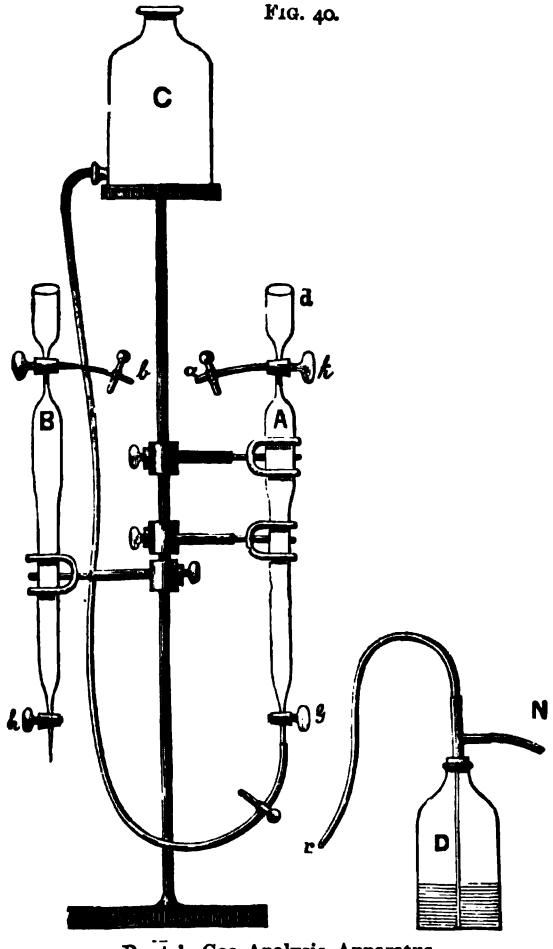
Bunte's Gas Analysis Apparatus.—A useful apparatus for the

Digitized by Google

determination of furnace gases is that devised by Dr. H. Bunte, Fig. 40, brought under the notice of English gas-engineers by the author of this section ("Jour. Gas Lighting," 1882, xl. p. 731). By means of this apparatus a ready and fairly accurate estimation of oxygen, carbonic acid, and carbonic oxide may be effected in a comparatively short space of time, thus enabling an operator with even a small amount of manipulative skill to ascertain the condition of the gaseous contents of the furnaces under his control.

A and B are two burettes fitted with three-way stopcocks, each capable of

FIG. 40.



Bunte's Gas Analysis Apparatus.

holding about 110 c.c., and graduated to fifths of a cubic centimetre; C is a one-gallon tubulated bottle serving as a water reservoir; D a suction bottle used for rarefying the gas subsequent to the introduction of reagents.

The burette A is first filled with water up to the stopcock by connecting it with C, the funnel *d* being also nearly filled. C is then disconnected from A and connection made between A and D; the gas to be examined is now allowed to flow in at *a*, the water flowing from A to D until the former is nearly empty. Connection is now re-established with C, and water allowed

Digitized by Google

to enter until the bottom graduation is reached, when the stopcock *k* is carefully turned in order to allow a portion of the gas (which of course is under pressure) to escape through the water in *d*, until there remains exactly 100 c.c. of gas at the atmospheric pressure. The apparatus is now under the proper conditions for analysis of the mixed gases.

Determination of Carbonic Acid.—The tube *r* of suction bottle is connected with the bottom of the burette, suction applied at N, the stopcock *g* opened, and most of the water allowed to run out; *g* is then closed and *r* removed; a solution of caustic potash is now applied, and *g* being opened, a quantity of the liquid enters; the burette is now taken from its support, the hand of the operator being placed firmly on *d*, and the gas is well shaken up with the liquid, this operation being again performed if absorption is found not to be complete. When complete, the stopcock at *k* is opened and water is allowed to flow down until the normal atmospheric pressure is reached, indicated of course by the water ceasing to flow. The amount absorbed by the caustic potash is now read off indicating percentage of CO_2.

Determination of Oxygen.—The caustic potash solution is drawn off by means of the suction tube, and an alkaline solution of pyrogallic acid is applied in a similar manner as in the estimation of carbonic acid; if oxygen is present, the solution becomes immediately a very dark brown, and the diminution in volume after shaking as before, and reducing to normal pressure, gives the percentage of oxygen.

Determination of Carbonic Oxide.—If oxygen has been proved to be present, carbonic oxide will most likely be absent, unless the gases have been brought together at a temperature insufficient to promote their combination.

In order to effect the estimation of carbonic oxide by absorption it is necessary to remove every trace of the alkaline pyrogallic solution by the use of the funnel *d* and the suction bottle; this done, a concentrated solution of cuprous chloride in hydrochloric acid is allowed to enter at the bottom of the burette as before; when absorption is complete, the cuprous chloride is drawn off, the tube washed, and treated with a solution of caustic potash for the purpose of absorbing any hydrochloric acid vapour which may have been liberated in the reaction; after bringing to the atmospheric pressure, the reading shows percentage of carbonic oxide.

The quantity of carbonic acid and of oxygen, however, give all the necessary information as to the working of a furnace. In the producer gas, the quantity of carbonic acid should be maintained as small as possible, and in the chimney gas oxygen should be present, but not in large quantities.

A more convenient apparatus—the Orsat-Muencke—for the rapid estimation of various gases will be described later.

CHAPTER VII.

Stoking Machinery, etc.

In many gas-works, machines worked either by hand or power, are employed for charging and discharging the retorts. The system devised by Messrs. Foulis and Woodward, and employed at the Gaythorne Road Works, Manchester, is thus described:—"The apparatus consists in the first place of two powerful breaking machines, which receive the coal and cannel direct from the railway trucks. These are placed one on either side of the retort-house at the end, and by the breakers the mixture of coal and cannel is reduced to about 3-inch cube size, in which form it is picked up from beneath the breakers by a series of self-filling buckets about 7 feet in length. By these buckets,

Digitized by Google

which are carried by means of an endless chain along two lines of light wrought-iron beams the entire length of the retort-house, the coal is conveyed to the charging machines. The buckets are made to empty their contents into the hopper of the charger in whatever position it may happen to be. From this hopper the material is delivered by a revolving four-bladed wheel into a vertical fixed trough; this contains three blades or valves, by the adjustment of which the material is directed into the charging scoop at three different levels, as required. The scoop, when charged, is driven into the retort by hydraulic power, turned over and withdrawn empty; this operation taking less than half a minute. The machine is then moved to the next retort, and the operation repeated. Preceding the charging machine is a hydraulic raking machine, which clears out the retort in from four to five strokes; leaving it ready for the charger. The breakers and buckets are driven by a 10-horse horizontal engine, and the charging and raking machines by a pair of simple horizontal ram pumps."

The improved Foulis hydraulic drawing machine, Fig. 41 (p. 50), and Arrol-Foulis charging machine, Fig. 42, are thus described by Mr. Foulis ("Transactions Incorporated Institution of Gas Engineers," vol. ii. p. 189):—

"The drawing machine consists of a light frame mounted on wheels and propelled by hand by means of bevel wheels and pinions. On one side is fixed an inverted ram, round the sheave attached to the head of which runs a short wire rope, one end of which rope is attached to the ram cylinder, and the other to the frame carrying the rake bar. By means of a valve, water is admitted to or exhausted from the cylinder, thereby raising or lowering the rake carriage to suit the height of the retort to be drawn. The rake bar is connected at one extremity to the carriage, which slides in a bar I-shaped in section. This carriage, and with it the rake, is propelled in either direction along the I-bar by means of two horizontal rams placed parallel therewith, but in opposite directions, connection being made with steel ropes running round the sheaves of each. Water is admitted to or exhausted from either ram alternately through a valve worked by a lever, which is also connected with the rope supporting the back end of the rake-carriage frame; the act of working the lever raises or depresses this frame, so that in entering the retort the rakehead is clear of the charge, and in leaving rests upon the bottom of the retort.

"A similar but reversed arrangement is used in the charger. In this the rakehead becomes a pusher, pushing into the retort measured portions of coal, the stroke automatically diminishing until the retort is charged. At one end of the machine is fixed a hopper having at its lower mouth a drum containing a series of blades. As this is revolved it permits the charge of coal to fall in measured portions on to a shoot resting on the mouthpiece, whence it is pushed into the retort as described. The automatic shortening of the travel of the pusher is effected by means of a shaft carrying a series of stops fixed radially thereto; the stops project upwards in rotation through corresponding openings in the I-shaped guide-bar, and these determine the distance the carriage is allowed to travel. A partial revolution of the shaft corresponds with each stroke made by the machine. The methods of raising and lowering the charging frame and hopper, and of propelling the machine, are similar to those described for the drawer."

The following particulars were given by Mr. Tysoe, East Greenwich Gas Works ("Transactions Incorporated Institution of Gas Engineers," vol. iv. p. 120):—

The quantity of water required for one set of machines working 200 retorts per 24 hours is 33,000 gallons, or about 140 gallons per ton of coals. This water, however, is utilised in the case of the drawing machines for quenching the hot coke after cooling the rake. The machines are only at

Digitized by Google

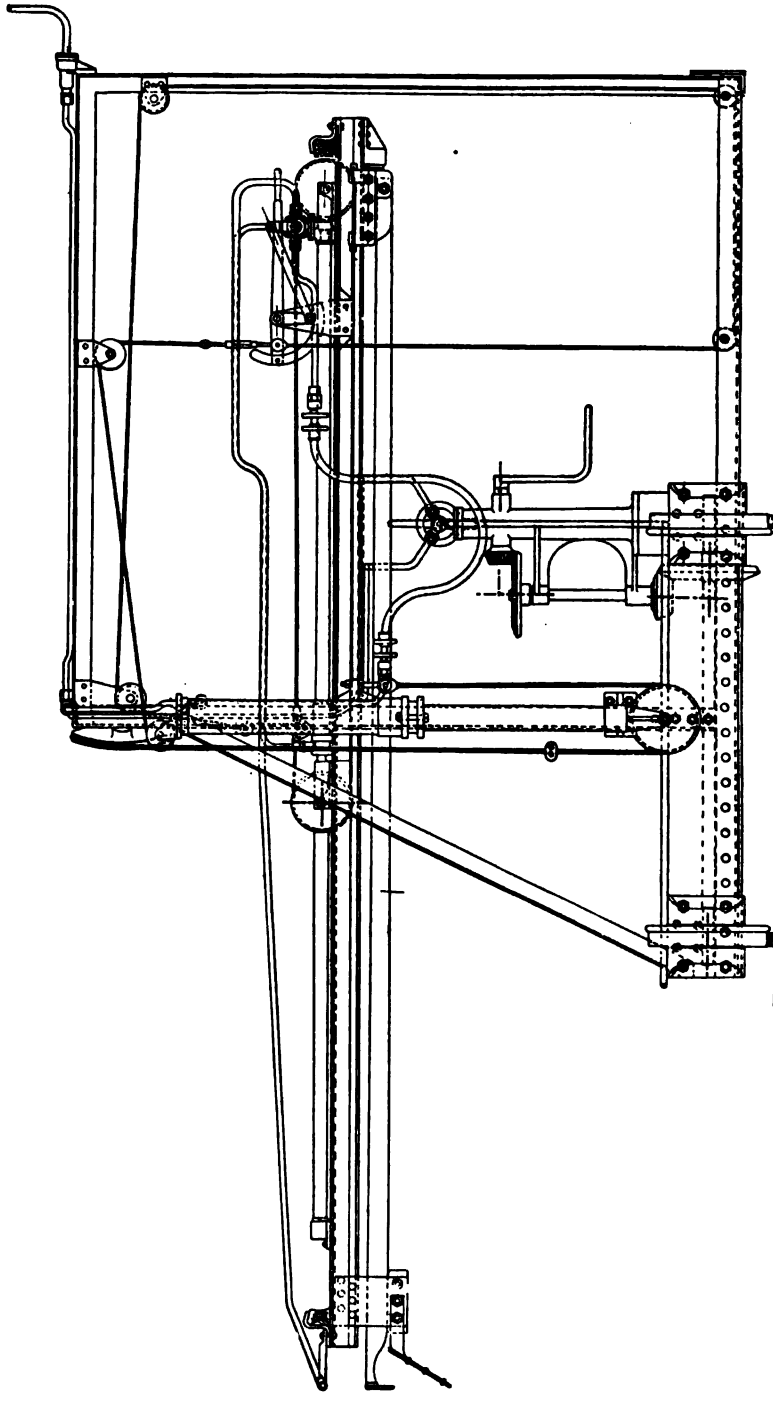


FIG 41.

Foulis Hydraulic Drawing Machine.

Digitized by Google

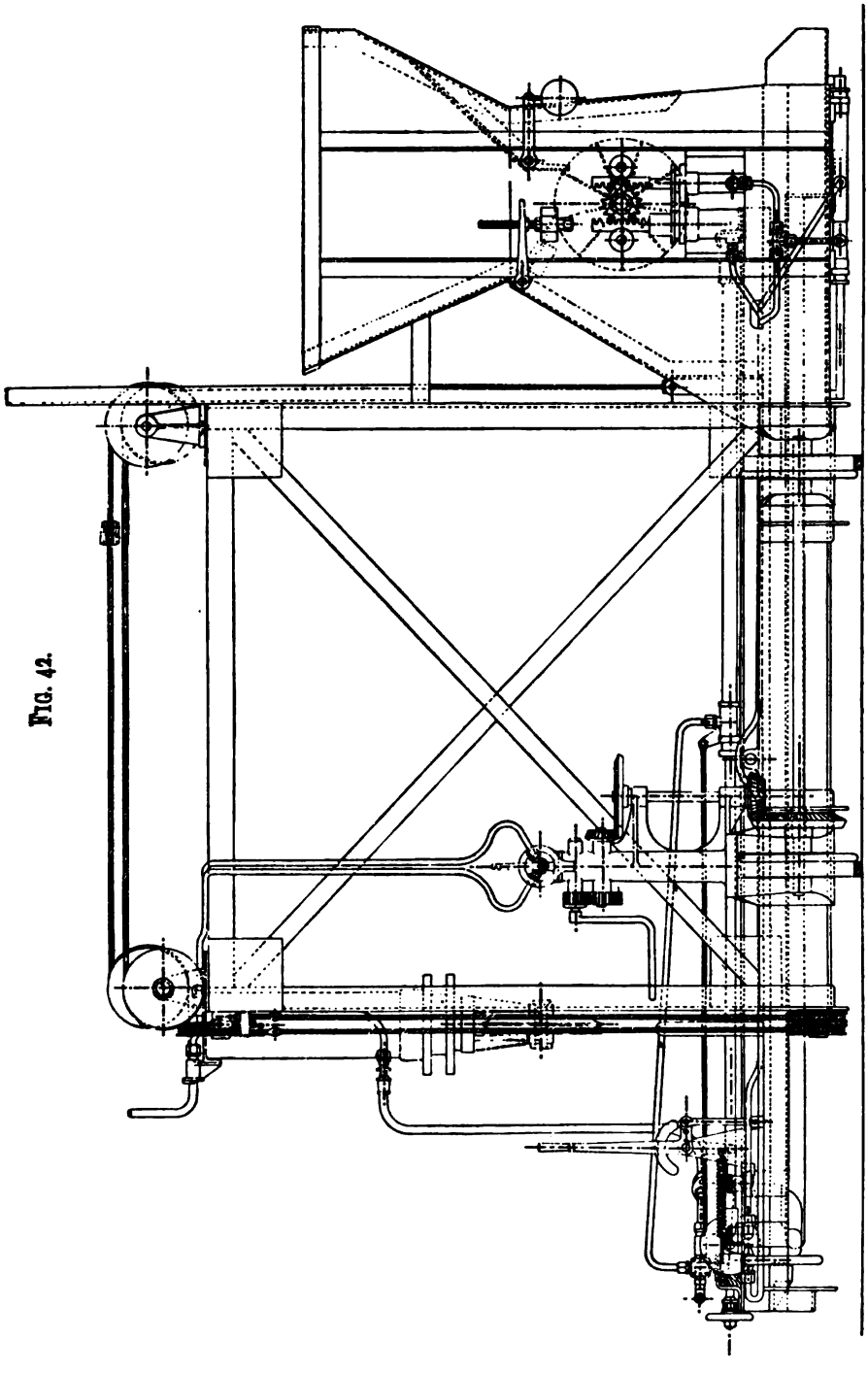


FIG. 42.

Arrol-Foulis Hydraulic Charging Machine.

Digitized by Google

work 7½ hours in every 12, and the number of men employed per 24 hours is 30. The total cost of carbonisation per ton by these machines (including maintenance, fuel, and 10 per cent. for interest and depreciation) is 12.5*d.*, as against 26.3*d.* for hand labour (including the necessary tools).

The practice of breaking the coal into small pieces for the purpose of facilitating the charging process was first introduced by Mr. John West, whose apparatus for charging and drawing is shown on Figs. 43, 44, and 45 (pp. 53–55). The coal, after having been broken up into pieces not larger than two inches cube, is lifted to a considerable height by an ordinary elevator, Fig. 44, consisting of a series of buckets attached to an endless chain, and deposited in an overhead hopper, capable of containing about 6 or 7 tons, from which a smaller one, holding about 2 tons, and attached to the charging machine, is supplied. This is used for filling the charging scoop, which is placed immediately beneath it. The machines are of two kinds, one being actuated entirely by hand, and the other by compressed air, conveyed to the centre or other convenient part of the retort-house, and supplied by a reducing valve through a 1-in. flexible hose at about 43 lbs. pressure. In both, the charging scoop is of special construction, having a flat bottom, with a series of openings provided with covers. When the scoop, filled with coal, has arrived within the retort, the covers are, by the movement of a lever, removed; the scoop is withdrawn, and the coal is left on the bottom of the retort. A modification of this arrangement is that wherein the scoop is made in two halves, each half being shaped similarly to a hand scoop. When it has been propelled into the retort the two halves are turned round in opposite directions, the coal being spread very evenly over the bottom of the retort. Occasionally a steam boiler attached to each machine is substituted for compressed air, and more recently a wire or cotton rope has been employed for driving the machines, the rope extending from end to end of the retort-house, and being put in motion by an engine placed in a convenient position outside the retort-house.

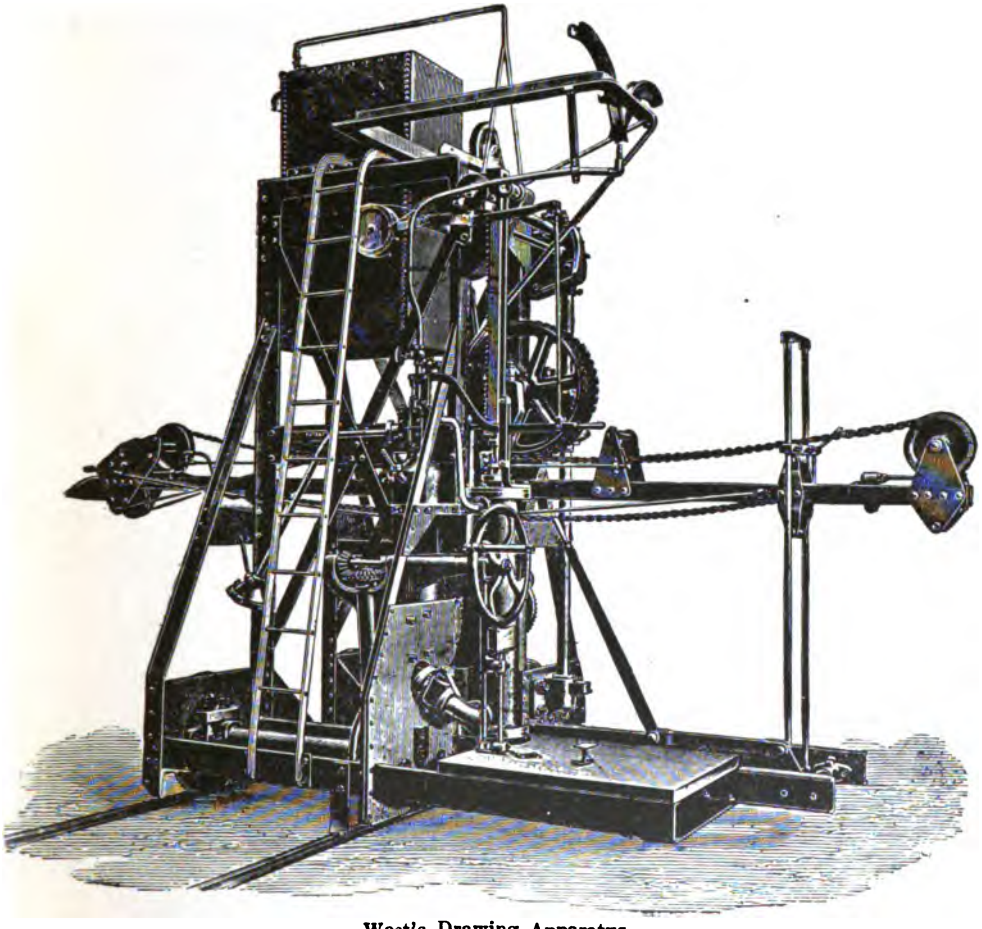
The Ross machine, Fig. 46 (p. 56), the invention of an American of that name, is the simplest contrivance of the kind at present in use. It is self-contained, comprising a steam boiler for providing the motive power; this travels with the machine, in which the scoop is dispensed with, the coals being deposited upon the bottom of the retort by the direct action of the steam, without the intervention of any mechanical appliance. Coals for charging the retorts are contained in a hopper fixed upon a supplemental carriage, which travels to and from the retorts upon rails laid on the platform of the carriage, and is supplied from an overhead store by means of shoots or feeders. The charging hopper is divided vertically into three compartments, each holding sufficient coal to charge one retort; when the three divisions are filled, the carriage is moved forward to the retorts, the nozzle of the hopper enters the mouthpiece, and two or three blasts of steam propel the charge from one compartment into the retort. The lid is then closed in the usual way. When the three compartments are thus emptied, the hopper is brought back to the nearest shoot, and refilled; this operation being repeated as often as required to complete the necessary number of charges.

A recent improvement, overcoming the inconvenience of having to lift or lower the hopper for each retort to be charged, is shown in Fig. 47 (p. 57). The hopper is divided into three compartments, each having a separate nozzle corresponding in position with the same number of retorts placed in vertical line. By this arrangement these retorts can be charged in rapid succession without the necessity of alteration of position. Above the hopper is placed a coal measurer, by which the weight of each charge can be regulated with great exactness.

Digitized by Google

Each of the systems above described comprises a separate machine for drawing the red-hot coke from the retort, an operation which is accomplished with great facility, the saving in labour by the use of machinery being largely derived from the drawing machines. At the Windsor Street Works, Birmingham, two men with the Ross drawing machines, Fig. 48 (p. 58), draw from seventy to eighty retorts every two hours; which, by comparison with hand labour, is a saving of about two-thirds; whilst by any of the systems, the economy resulting from both operations is usually reckoned at from 45 to 55 per cent.

FIG. 43.

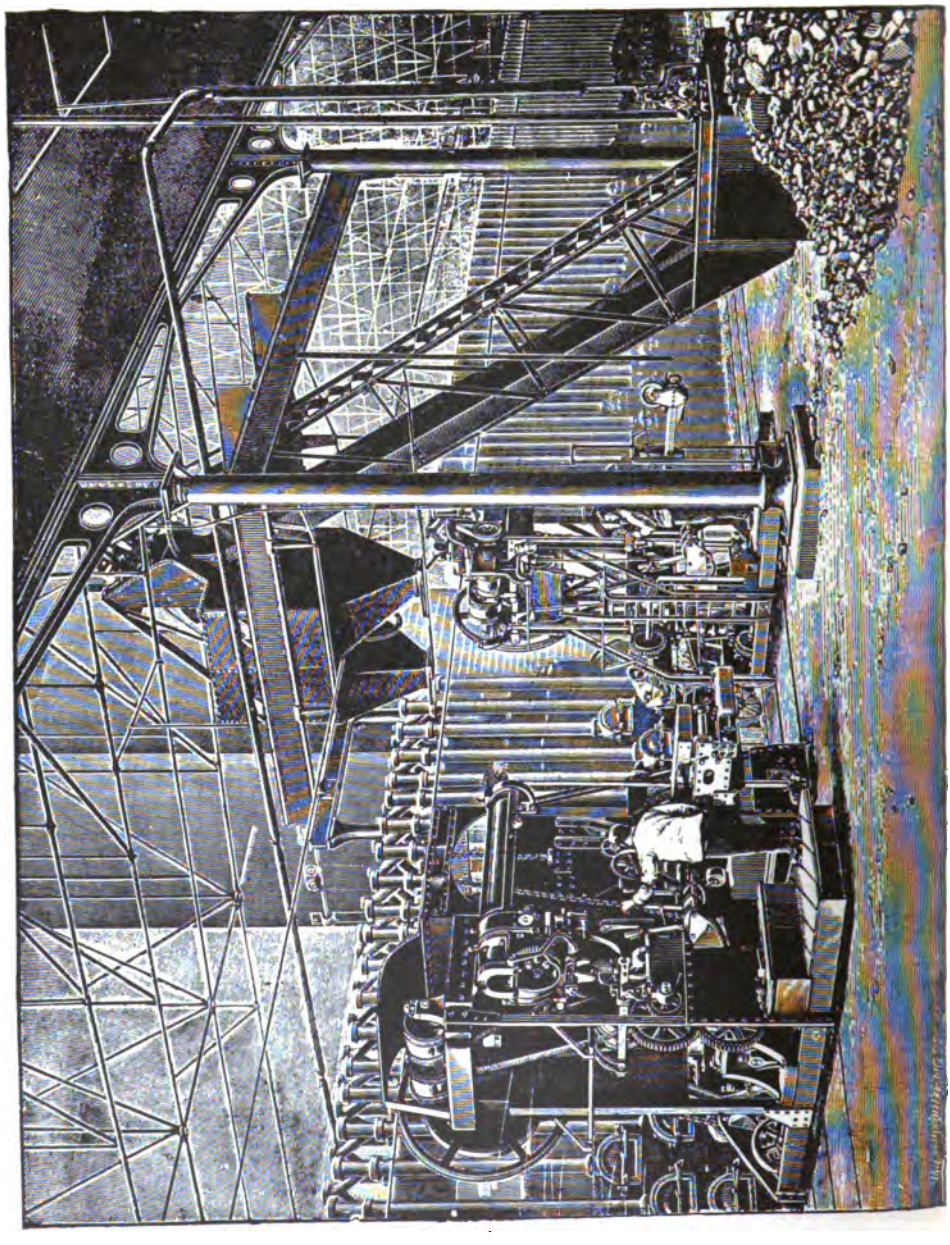


West's Drawing Apparatus.

From the ordinary arrangement of the retorts, and the process of distillation carried on in them, the favourable circumstances under which the gas is at first evolved do not continue, and the last portions of gas are never so rich in illuminating matter as the first. The revolving web retort, already described, would, if practicable, certainly tend to diminish this inequality; other plans have also been suggested with the same view. Heginbotham

Digitized by Google

FIG. 44.



West's Machinery (General View).

Digitized by Google

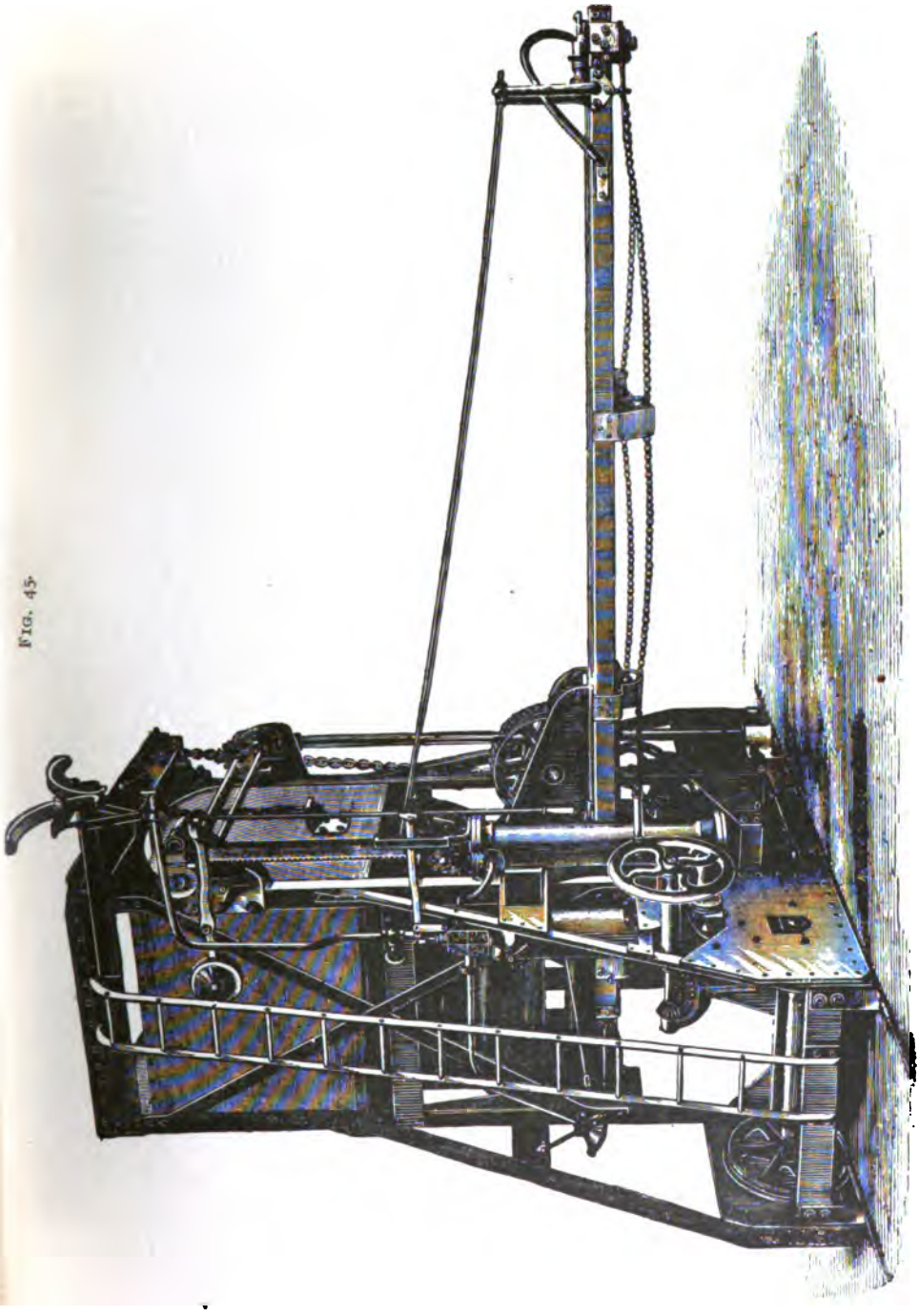


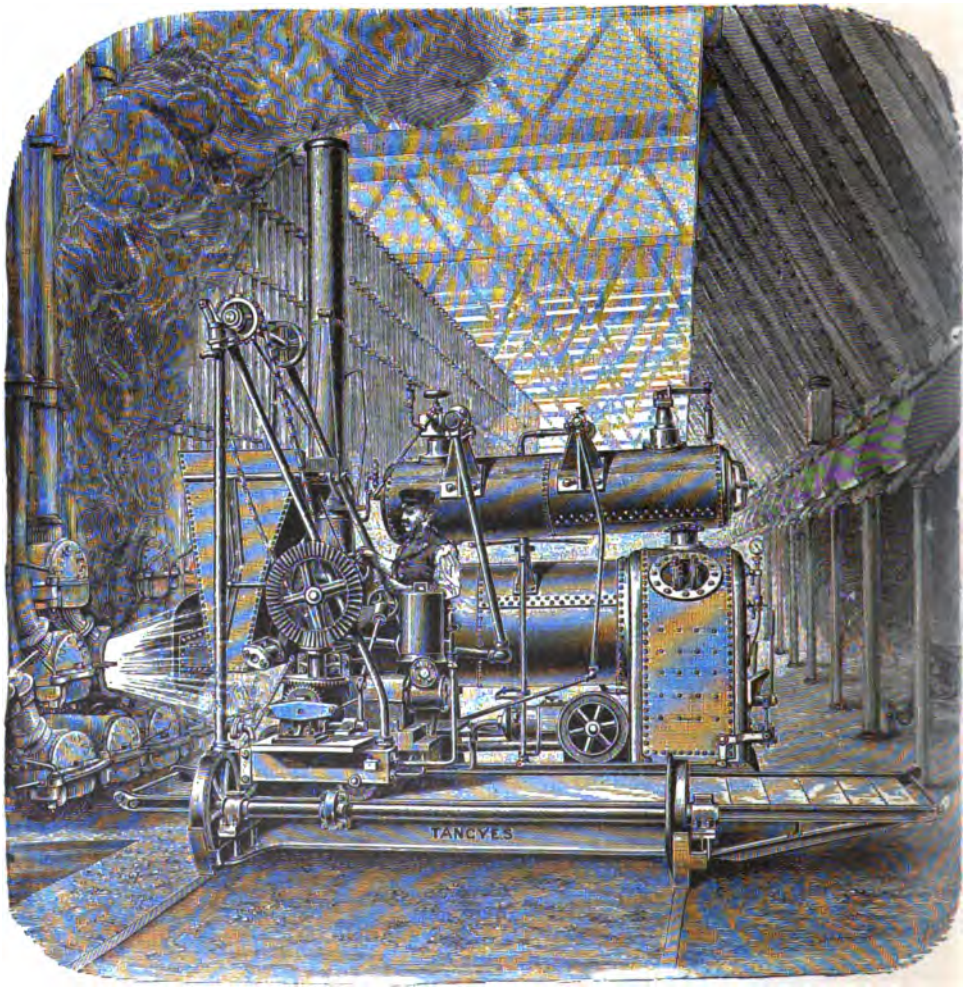
FIG. 45.

West's Charging Machine.

Digitized by Google

proposed that the retorts should be furnished with a rotating screw of the same length as the retort, the blades of which worked against the interior surface. This plan is very similar to that subsequently adopted for the distillation of sawdust, spent-tan, &c., and described in vol. i. "Fuel," p. 608. It has likewise been adopted at various collieries for the distillation of fine coal or duff, which is fed continuously into the retort at one end, and slowly

FIG. 46.



Ross Charging Machine.

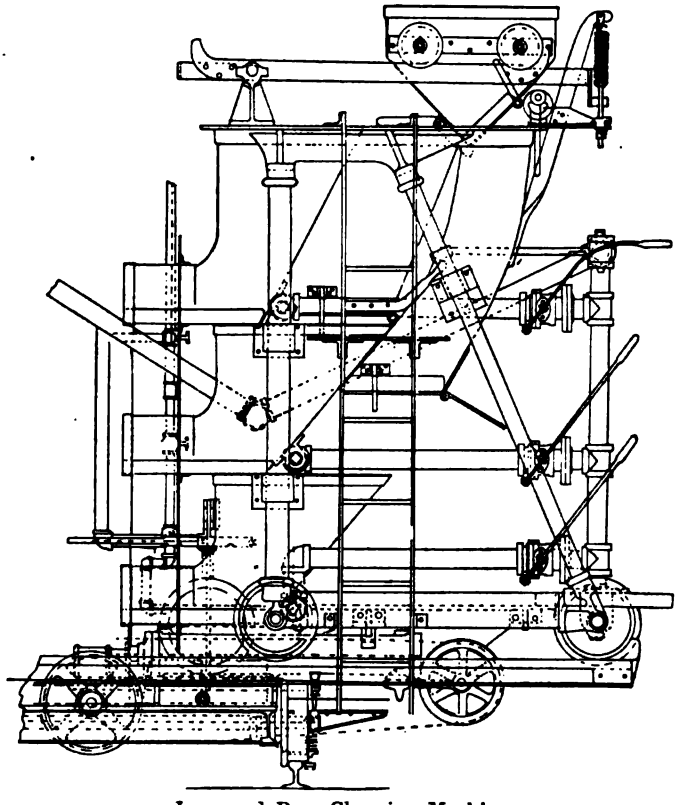
propelled by the screw through the red-hot chamber, to be expelled at the opposite end, where it falls, as coke, through a funnel into a closed water-tank. The excessive evolution of hydrogen towards the end of the operation does not occur with this apparatus, but the wear and tear and bad quality of coke produced must continue to be serious objections to its general adoption.

Digitized by Google

Reference has already been made to the apparatus for continuous carbonisation devised by Mr. J. Elliott. It is thus described by Mr. Henry Hack in a paper read before the Midland Association of Gas Managers (Reports, Gas Associations, 1891, p. 305):—

The retorts used were "18 inches in diameter at the front or charging end, and 20 inches at the discharging side; the length over all on the horizontal being 10 feet, and 11 feet 6 inches on the slope, the fall of the bottom of the retort from the front to the back being 20 inches, making an angle of 8° with the horizontal. The increase in the diameter of the retort at the coke cylinder end is given, as will be readily understood, to prevent

FIG. 47.



Improved Ross Charging Machine.

wedging of the coke; and so, apart from the slope, afford additional facility in the operation of discharging.

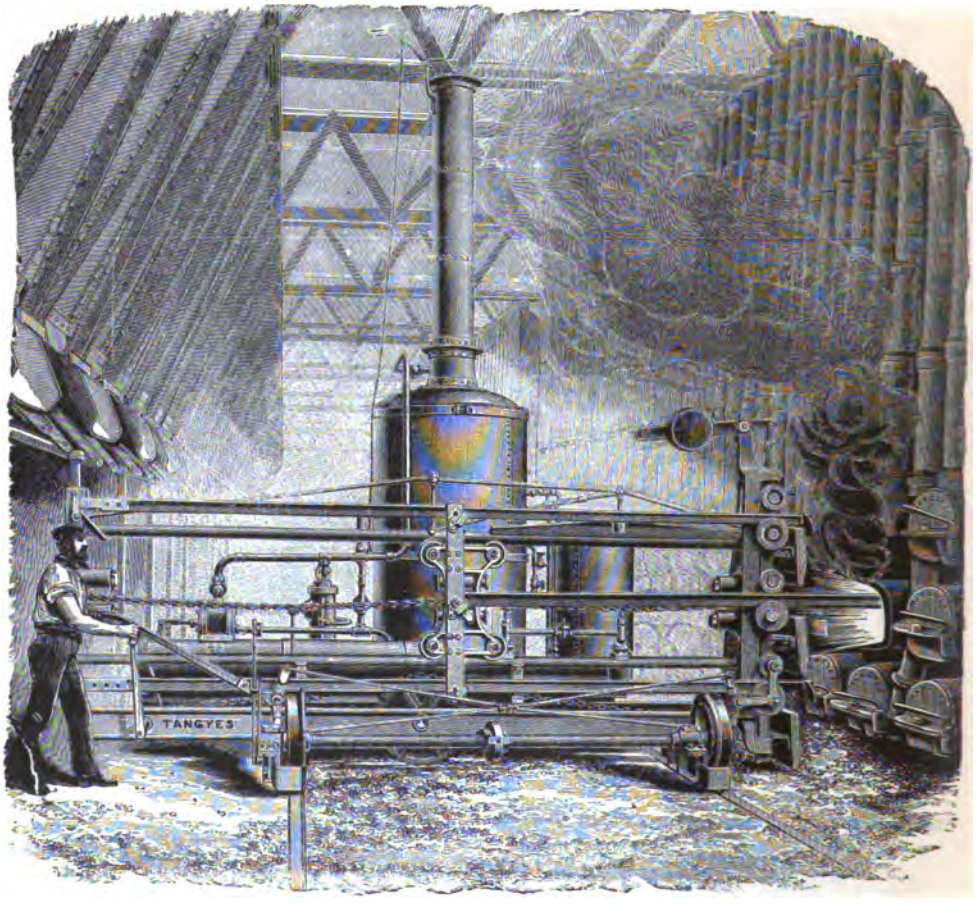
"Before commencing the operation of charging the retorts, both ends of the feed-pipes *A*, Fig. 49 (p. 59), are closed by the sliding plate *B* and the throttle valves *D* respectively. The broken coal is then tipped into the hopper, and by means of the lever *C* the sliding plate *B* is moved until the holes in it are concentric with the feed-pipes *A*. Thereupon the coal falls into the five pipes as far as the throttle-valves *D*, and the sliding plate is moved back into its original position. Upon working the levers *E* and *E* the throttle-valves *D* are opened, thus allowing the coal to fall through the breeches pipe *F* into the scoop *G*, which is in position within the

Digitized by Google

mouthpiece *H*. The levers had to be worked to and fro several times to cause the whole charge to clear the valve, which caused an obstruction when opened to the extent of about one-third of the area of the pipe. After the coal has fallen the throttle-valves are immediately closed.

"The five scoops *G* (with the coal in them) are now propelled into the retorts by the frame and shafts *K*, which in their turn are actuated by the hand-wheels *J*. When the scoops have advanced into the retorts the required distance, they are turned over by working the cranks *L*, depositing

FIG. 48.



Ross Drawing Machine.

the coal upon the bottom of the retorts. The scoops are now drawn back into the charging mouthpieces *H* by reversing the motion of the hand-wheels and the frame and racks *K*, and are then turned into their original positions ready for the next charge. As the scoops advance into the retorts they are intended to push forward the partly carbonised coal and the coke in front of them, causing that portion nearest the discharging end to fall through the mouthpieces *M* into the coke cylinders *N*. When the coke has cooled down to blackness, or earlier if found more convenient, the cylinders *N* are rotated by working the cranks or ratchets *O* connected to the spindles

Digitized by Google

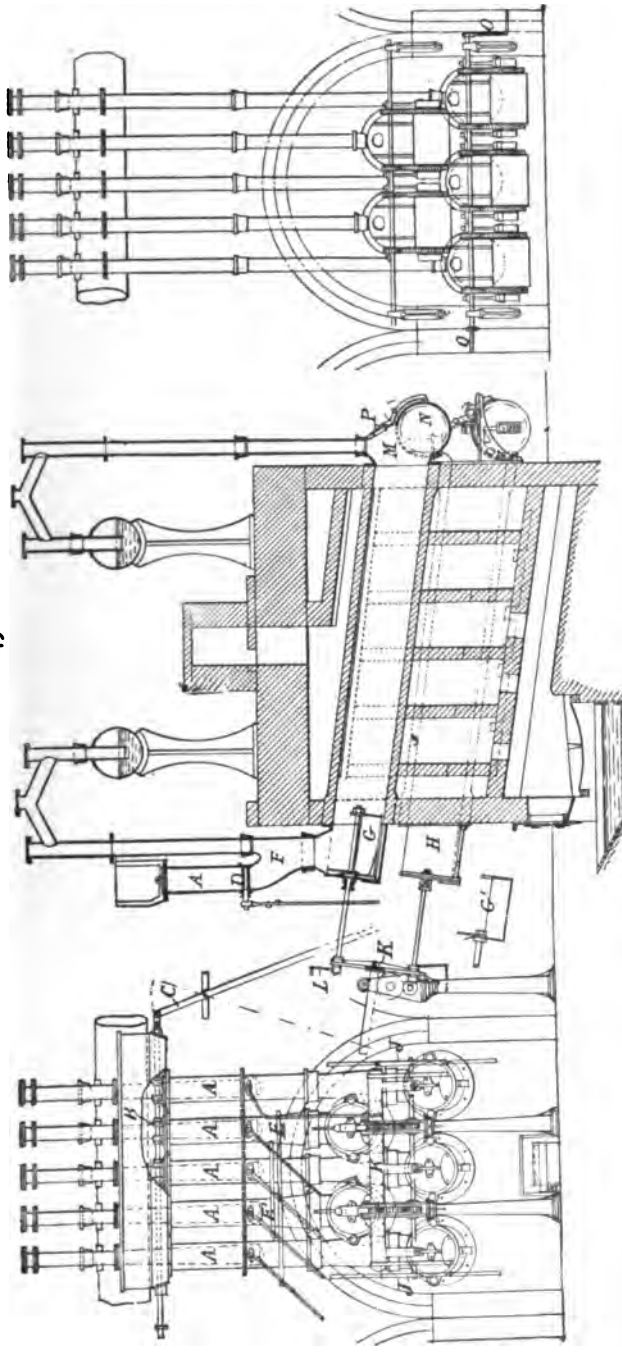


FIG. 49.

Elliott's Continuous Carbonisation.

Digitized by Google

or spur-wheels; the coke falling out of the cylinders into iron barrows or other suitable receptacles. The cylinders are then reversed, ready to receive the coke forced out at the next charge."

The result of Mr. Hack's trial of this process was that it could not be regarded as satisfactory, a serious diminution in the yield of gas, tar and liquor being found to occur.

Continuous distillation was likewise aimed at by Mr. Andrew Scott, by means of a conical vertical retort. The wider end was sealed in a trough of water, from which the coke as formed was withdrawn. The upper end was provided with the usual hopper and valve, into which the coal was shovelled from the waggons; and the gas outlet was situated at such distance up the side of the retort that the coal had there lost all its volatile matter. Four such retorts were heated in one oven.

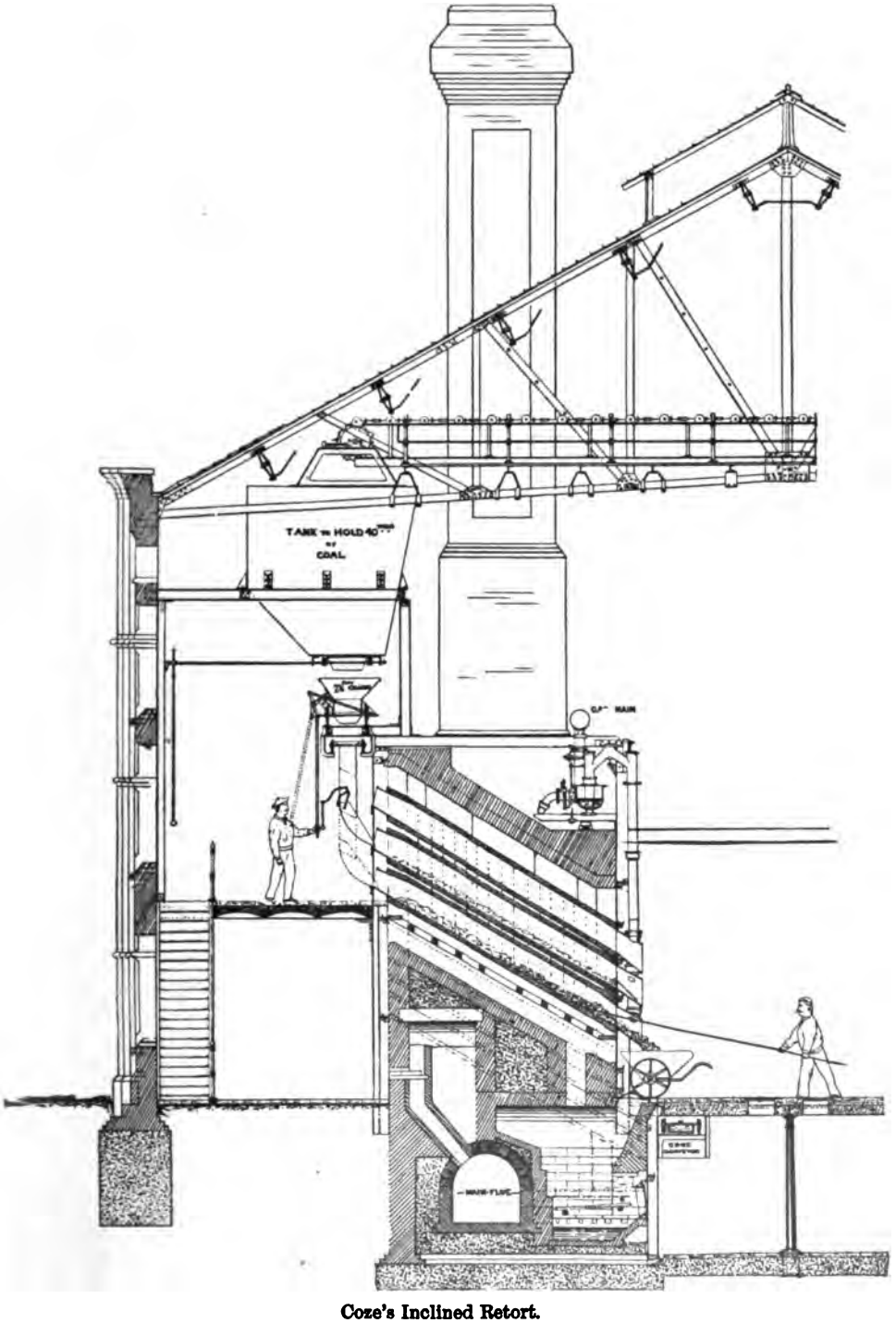
The system of inclined retorts, devised by M. Coze, Engineer of the Rheims Gasworks, and described by him in the Transactions of the "Société Technique de l'Industrie du Gaz en France," 1885, has been applied with success. The retorts are set at an angle of 29° to 32°, which corresponds with the angle of repose of the coal. They are furnished at the upper or charging end with a bend, rising a few inches above the top of the retort bench, from which the retorts are charged. The coals are brought into position in balance scoops mounted upon a carriage which is made to run along a pair of rails laid at the required height. In rapid succession the lids which cover the mouths of the bends are thrown back, the scoops tilted over and emptied of their contents, lifted back, and the lids replaced and secured, the whole operation occupying only a few seconds. A guard or stop placed in the mouthpiece at the discharging end prevents the coal from falling out of the retort. When the charge is burnt off, this stop is removed, and the coke dislodged by means of a light steel rod, driven up between it and the bottom of the retort. As the pieces become detached they roll down and fall into the barrow placed to receive them. This operation occupies very little time, and is performed with great ease. Experiments made at Rheims have proved the adaptability of the system to English coal, no difficulty having been experienced from its caking together. The retorts are charged every four hours, producing upwards of 10,000 cubic feet per mouthpiece. The saving in labour by this arrangement is estimated at 60 per cent. Were all the advantages claimed for this system invariably obtained, it certainly would be the system *par excellence;* for it means charging and drawing the retorts with the minimum of labour and machinery, together with even distribution of the coal in the retort. Where, however, different qualities of coal as regards size are used, much trouble is frequently experienced.

As applied by the inventor, the system is adapted for "single" retorts, that is, from 9 to 11 feet long, but, at Brentford, Mr. F. Morris has applied it to "through" retorts, having a length of about 20 feet. Simultaneously, at Birmingham, Mr. C. Hunt has adopted a setting of nine retorts having a length of 22 feet 9 inches. In both cases, the fixed bends are dispensed with, arrangement being made for charging by means of a movable hopper. Fig. 50 shows Mr. Winstanley's application of the Coze system at the Coventry Gas Works.

Hydraulic Main.—The ascension pipes which convey the gas from the retorts vary in size from 5 to 8 inches in diameter and rise to a height of 3 or 4 feet above the hydraulic main, where a semicircular bridge or saddle-pipe connects them with the dip-pipes, the latter entering the liquid in the main. A cap is usually fitted to the upper extremity of both the ascension and dip pipes for the purpose of cleaning. The hydraulic main

Digitized by Google

FIG. 50



Coze's Inclined Retort.

Digitized by Google

itself is a large pipe of cast or wrought iron, the latter material being usually preferred for its lightness and freedom from liability to crack under variations of temperature. It is made either square, oval-shaped, or as shown in Figs. 51 and 52, with the bottom sloping several inches towards the back, to facilitate the removal of the tar as it is formed. Into the hydraulic main, which is placed in a perfectly horizontal position, and partly filled with the liquid products of the distillation, the dip-pipes are secured air-tight, with their mouths dipping from $\frac{1}{2}$ to 2 inches

FIG. 51.

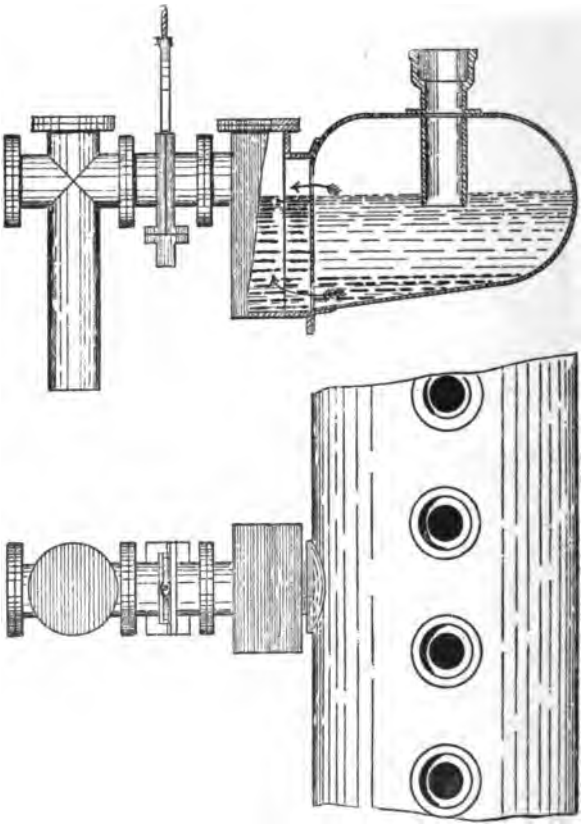


FIG. 52.
Hydraulic Main.

below the level of the liquid. A perfectly secure seal is thus effected, the area of the main depth of seal, and height of dip-pipes being so adjusted, that even in the event of a stoppage of the exhauster, the liquor cannot be forced by the pressure of gas so far up the dip-pipes as to cause it to overflow, or to unseal the others when one or more of the retorts are open during the operation of charging or discharging.

The hydraulic main is usually placed above the brickwork of the ovens, but supported independently upon wrought-iron joists carried upon columns rising from the retort-house floor, so as to avoid the risk of alterations of

Digitized by Google

level consequent upon the expansion and contraction of the brickwork. One pipe in the upper part of the main conducts away the gas to the condensers, whilst another, fixed just above the level of the liquid in the main, carries away the liquid products to the tar well, the escape of gas or ingress of air being prevented by a syphon fixed at some intermediate point. Another plan is to convey away both gas and liquid products by the same pipe as far as the condensers, where separation is effected. This prolonged contact between the gas and tar is believed to have the effect of preventing the after deposition of naphthalene. Experience, however, appears to have proved the desirability of an early separation of the heavier portions of the tar, and this is well effected by the weir arrangement shown in Fig. 51; in which the valve may be raised or lowered, so as to alter the seal of the dip-pipe, as occasion requires. Through the valve, the whole of the tar passes from the hydraulic main, in another portion of which a pipe is fixed at a somewhat higher level. This forms an overflow for the liquor, which, being lighter than tar, collects above it.

In this way, separation of the two is effected, and the pressure within the retorts is much reduced by the lesser resistance offered to its passage by the liquor as compared with what it has to overcome when the hydraulic main is allowed to become filled with tar. For more completely effecting this object, it has been proposed to convey the tar by means of a pipe from the bottom of the hydraulic main to a receiver placed in some convenient position, and capable of containing, say, about two-thirds of the daily production. The top of the receiver is connected by a second pipe with the hydraulic main, a little below the level of the liquid; and each pipe is provided with a cock or valve. When commencing to work, these cocks are opened, and liquor is turned into the receiver from the storage tank until, flowing back through the pipes into the hydraulic main, it reaches the overflow, which also may be the gas outlet. The tar which is formed, collects in the receiver, displacing the liquor, which rises into the hydraulic main and from thence overflows; when the receiver has become filled with tar, the cocks on the connecting pipes are shut and the receiver emptied. As soon as all the tar has drained off the receiver is again filled with liquor, and communication with the hydraulic main restored by opening the cocks. This operation has to be periodically repeated, its frequency depending on the capacity of the receiver. The arrangement forms the subject of a patent taken out by J. Dillaman.

With the object of entirely removing the pressure within the retort, many contrivances are resorted to as substitutes for the hydraulic main and dip-pipe, one of the simplest being a throttle-valve of ordinary construction fixed on the upper part of the ascension-pipe, or in the cross pipe leading therefrom to a foul main, which in this arrangement takes the place of the hydraulic main. Before opening the retort the workman closes this valve by means of a rod extending upwards from the mouthpiece to a lever attached to the valve. As soon as the retort has been fresh charged and the lid secured, the valve is reopened by the same means, the products of distillation passing through it into the foul main. Another contrivance is "White's" patent gas valve, used either alone, or in combination with, a dip-pipe and hydraulic main. This is self-acting, a very slight pressure from the gas as it is evolved sufficing to open the valve, which closes as soon as the pressure is withdrawn on opening the retort. By means of a lever, a second valve is actuated, if at any time it should be found necessary to clean or adjust the working valve.

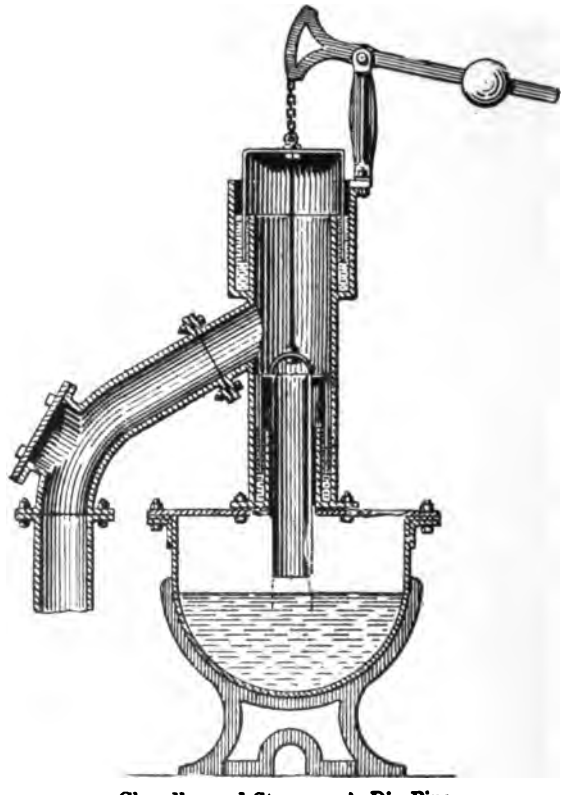
Chandler and Stevenson's self-acting removable dip-pipe, Fig. 53 (p. 64), is stated to act with great certainty, no attention being needed after it has been once set. Its automatic movement is accomplished by means of a

Digitized by Google

small balanced holder, capable of being actuated by half an inch of pressure; this, so long as the retort is closed, and gas is being produced, sustains the dip-pipe in its position on the surface of the liquid in the hydraulic main. As soon as the retort is opened, the end of the pipe is immersed in the liquid, and so remains until the retort is again charged and the lid closed.

Retort-house.—This may be either a "ground floor" or a "stage" house. In the former, generally built for small works, the retorts are charged from the ground floor, and the hot coke drawn from the retorts into barrows and wheeled outside the house to the coke heap. "Stage" retort-houses are

FIG. 53.



Chandler and Stevenson's Dip Pipe.

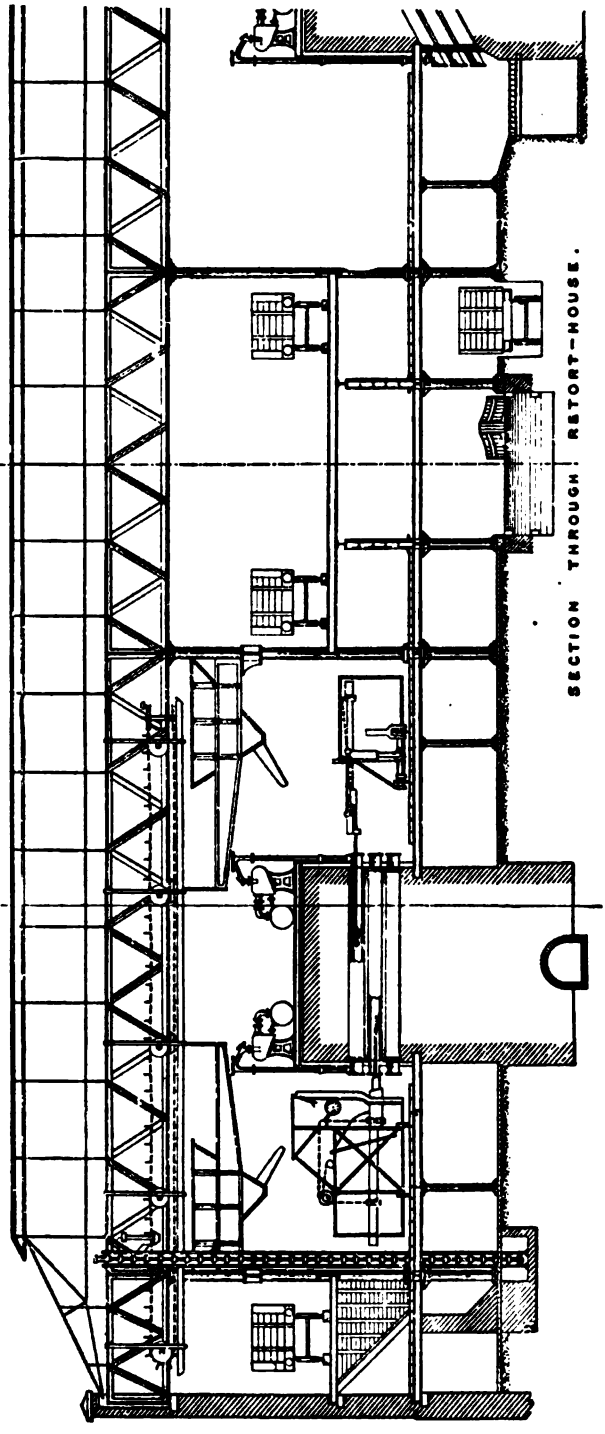
provided with a second floor or "stage," and are a convenience where regenerator furnaces and stoking machinery are employed.

As the success of an undertaking mainly depends on the proper carrying out of the work of carbonisation, it is of the utmost importance that the retort-house should be designed so as to afford the greatest facility, with minimum of labour, in the handling of the raw material, coal, and of its bye-product, coke.

Fig. 54 shows a section of the retort-house at the Windsor Street Gas Works, Birmingham, containing about 1500 mouthpieces, in the designing of which this necessity was kept prominently in view.* Coal is brought

* Hunt on the Construction of Gas Works: "Proc. Inst. Civil Engineers," vol. cxvii.

Digitized by Google



SECTION THROUGH RETORT-HOUSE.

FIG. 54.

Digitized by Google

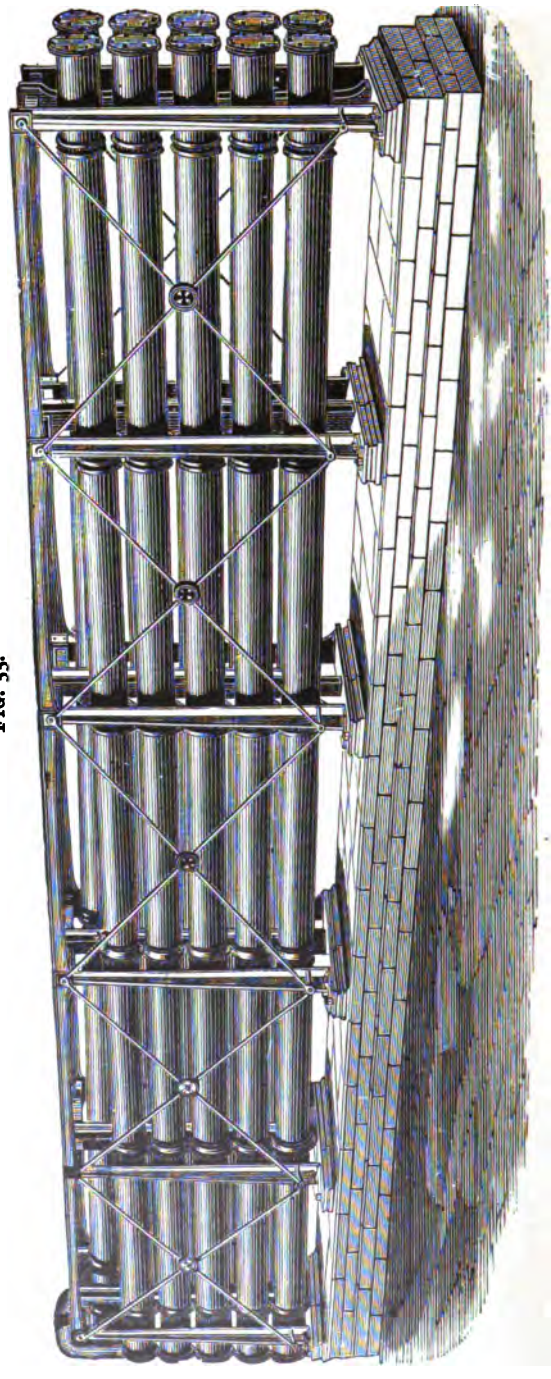


FIG. 55.

Graham's Horizontal Flat-Screw Condenser.

Digitized by Google

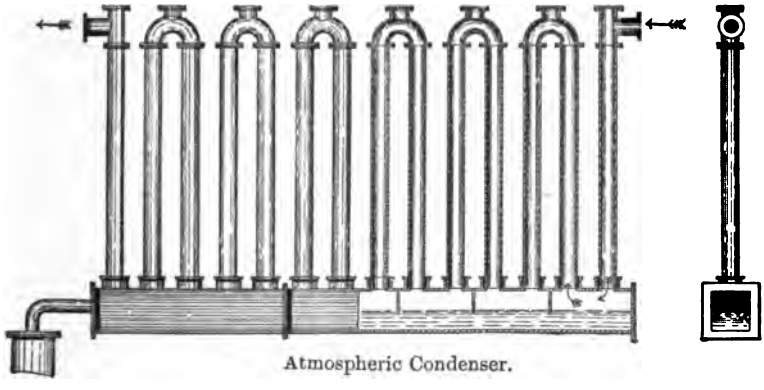
into the house by overhead rails, in railway waggons, many of which are of a hopper shape, and provided with sliding doors at the bottom worked by a rack and pinion. The mere turning of a handle, therefore, allows the coal to fall from the waggon through the coal breaker, and it is then in a proper condition to be lifted by the elevator into the overhead hopper, from which it is supplied to the charging machines as required. The coke is very economically removed in barges brought into the house by an arm of the canal, and also by means of railway coke trucks, which are loaded in the dock, shown on the ground floor.

CHAPTER VIII.

Condensation.

As the hot gas issuing from the hydraulic main is laden with condensable tar and aqueous vapour, which, if allowed to condense in distant parts of the apparatus, might occasion considerable inconvenience, and altogether prevent purification, it is conducted to the coolers, or condensers, which are variously constructed, but have all the common object of cooling the gas. The condensers may be either "atmospheric," where the atmosphere is the cooling medium, in which case, owing to the great variation in atmospheric temperature, they are more or less uncontrollable; or what are known as "water condensers," where water is employed as the cooling medium. If such water can be obtained from a deep well not influenced by the summer heat, this class of condenser is completely under control. A compact

FIG. 56.

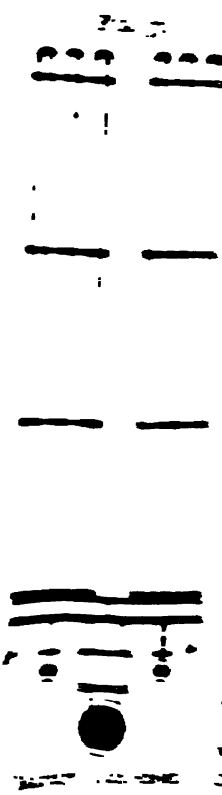


Atmospheric Condenser.

form of atmospheric condenser is shown in Fig. 55, and is known as Graham's horizontal flat-screw condenser. It consists of two series of pipes, the number and size of which depend on the quantity of gas to be dealt with; and through these pipes the gas passes from top to bottom. Each length of pipe has a blank flange at each end for cleaning purposes, and is set with a fall, so that the gas in passing through the two tiers is continually on the descent. The condenser is supported by a framework provided with sliding wooden panels for the purpose of regulating the temperature.

It is now generally admitted that whereas contact of the gas with the lighter portions of the tar whilst both are at a high temperature is beneficial to the gas, it is desirable to withdraw all tarry matter, more especially the heavier portions, as quickly as they cool down; about 32° C. (90° F.) being the limit of temperature below which the tar and gas ought not

Digitized by Google



Digitized by Google

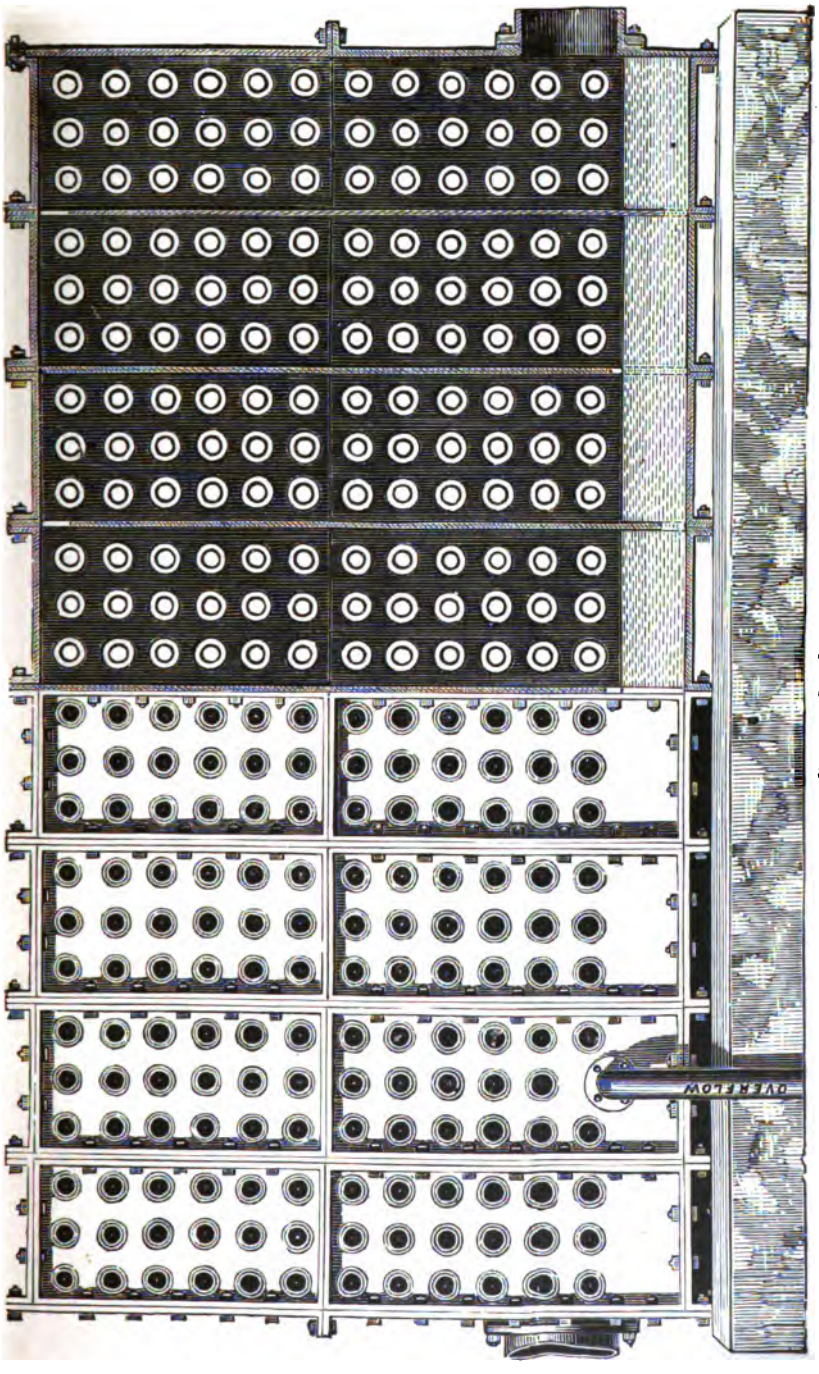
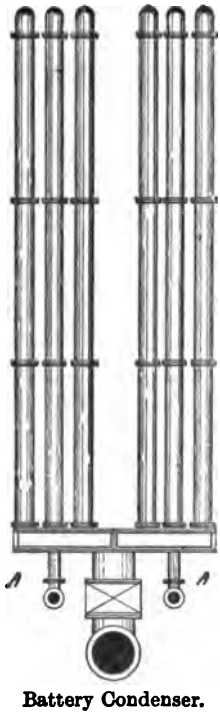


FIG. 58. Battery Condenser.

Digitized by Google

to remain in contact. The simplest form of condenser which effects this object is that shown in Fig. 56. It consists of a quadrangular casting, having bottom and end plates bolted to flanges, with sockets at top to receive the upright pipes, these being from 6 to 9 inches in diameter and of any suitable height. Within are division plates corresponding with each pair of upright pipes, and extending nearly to the bottom of the vessel, leaving a space for the liquid products to pass freely to the outlet provided for them.

FIG. 57.



Battery Condenser.

This condenser is constructed with either one, or more, rows of pipes, as may be required. Fig. 57 shows an arrangement of six rows of pipes, each 9 in. in diameter and 24 ft. high, employed for a daily production of from 2½ to 3 million cubic feet of gas. The gas is divided up into six separate streams, each stream passing through a series of 36 pipes; the total number of pipes forming the condenser being 216. Descending pipes *A A*, each terminating at the end of the condenser with a rising syphon, are used for carrying off the liquid products.

Another form of condenser is that known as the "battery," Figs. 58, 59, and 60 (pp. 69 and 71), which is an oblong vessel, of variable height and width, having division plates at intervals extending to within a short distance of the top and bottom alternately, the gas passing up and down the divisions thus formed from inlet to outlet. Two or three inch tubes open at each end to the atmosphere passing through the vessel from side to side, where they are properly fixed, cool and break up the current of gas, thus causing a separation of the condensable vapours. Suitable syphons are fixed to each division for carrying away the liquid products.

Kirkham very much increased the power of the condenser, by causing the gas to pass up and down alternately through a space of 5 or 6 inches, included between two concentric pipes, through the interior of which air could circulate. In Wright's condenser, the gas was obliged to pass in a contrary direction to the current of air through the ventilating columns, and not alternately up and down, whilst, by means of a cap fixed upon the ventilating column and removable at will, the current of air was regulated, and the condensation kept under control.

Fig. 61 (p. 72) shows a section, elevation, and plan of Wright's condenser. The external column C^1 is 3 feet in diameter and 18 feet high; the internal column A is 2 feet in diameter, the ring of gas between the two being 5½ inches wide, with an area nearly equal to that of a pipe 26 inches diameter. The transfer of the gas from the base of one column to the top of the next, is effected by 12-inch socket pipes. Covers are supplied for the inner ventilating pipes, which enable the current of air to be regulated according to the temperature. The number of the columns required will depend on the quantity of gas passing, but, as an illustration of their effective value, an experimental result, in which eight columns were used, is here given.

The temperature of the air being 12.8° C. (55° F.), rain falling, and the covers being removed from the ventilating pipes, with 12,400 feet of gas passing per hour, the gas was cooled in the following ratio by the several columns:—

Digitized by Google

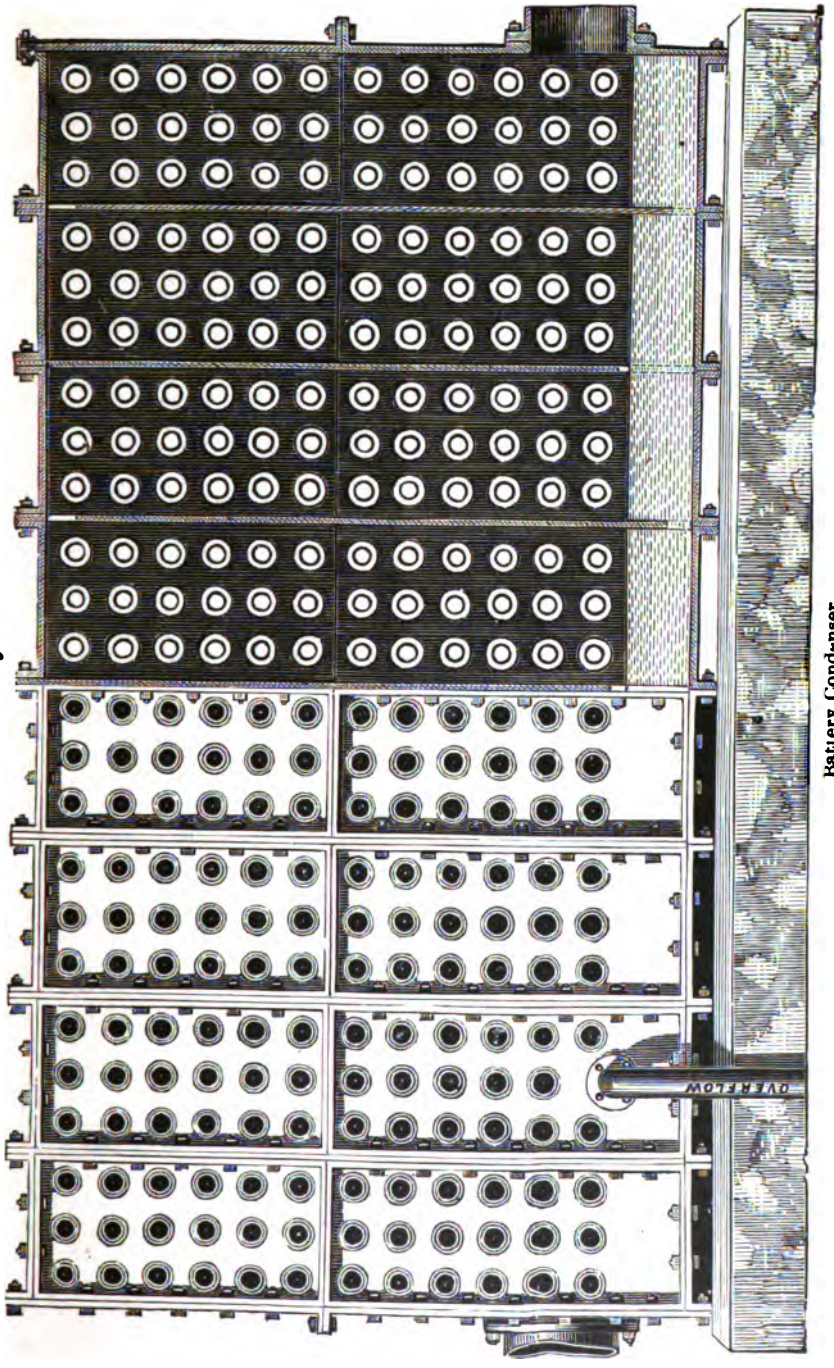


FIG. 58.

Battery Condenser.

Digitized by Google

TEMPERATURE OF GAS.

Inlet.	Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.	Col. 7.	Col. 8.
103°	79°	67½°	61°	58°	56½°	56°	55½°	55° Fahr.

It will be seen from these observations that this quantity of gas was effectively cooled by four columns, only 3° F. of temperature being lost by its passage through the last four columns.

Condensation may be, and probably is, occasionally carried too far; part of the luminous hydrocarbon vapours being condensed with the tar. From the investigations of Mr. Lewis Thompson, it appears that the hydrocarbon vapours contained in Newcastle coal gas at 60°, having a specific gravity of 3.2, are condensed at a higher temperature than those existing in Boghead Cannel and Wigan Cannel gas, having the specific gravities of 1.21 and 1.77 respectively, so that the latter may be cooled to a greater extent than the former, without injury to the illuminating power of the gas. It thus appears that the process of condensation should be under control, and the extent to which it is carried modified according to the nature of the gas and the temperature of the external air. Common coal-gas experiences a rapid diminution of illuminating power when cooled below 10° C. (50° F.), although cannel gas will bear a lower temperature unimpaired.

The sudden and considerable variations which are continually taking place in the temperature of the atmosphere necessarily occasion great uncertainty in the action of condensers depending on atmospheric air as the cooling medium, and water is by many engineers preferred, as being more completely under control.

The relative effect of water and air as cooling agents for gases has been studied by Peclet and others, and the following table exhibits the results obtained.

Excess of Temperature in the Gas.	Quantity of heat lost by a square unit of exterior pipe surface.	
	When radiating in open air.	When plunged into water.
For an excess of 10°	8	88
" " 20°	18	266
" " 30°	29	5,353
" " 40°	40	8,944
" " 50°	53	13,437

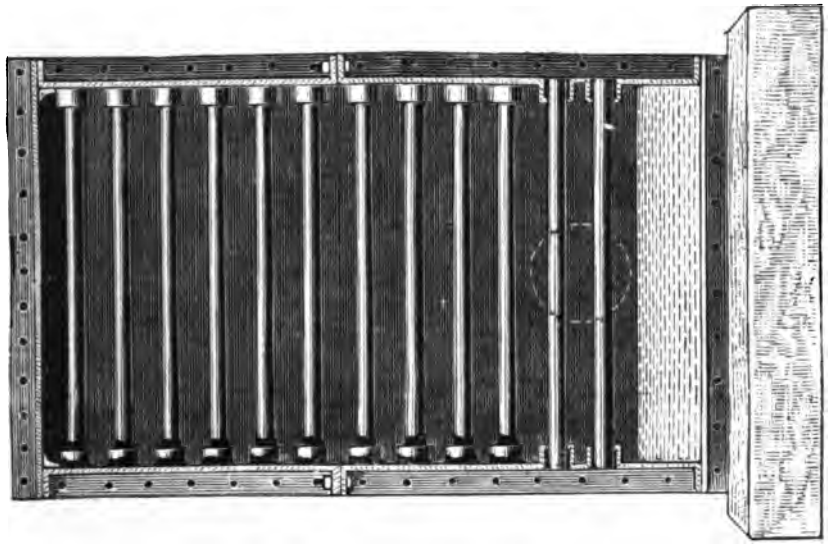
It will be seen from this table that when the difference of temperature between the gas and the water employed for cooling is only 10°, the effect of the water is considerably greater than that of air when the difference of temperature is five times as great.

One of the most successful condensers in which water is employed as the cooling medium is that patented by Messrs. Morris and Cutler, called by them the "Perfect Condenser," and shown on Figs. 62, 63, 64, and 65 (p. 74). The water is distributed through the condenser in small wrought-iron tubes as shown in Figs. 63 and 64, the supply to each tube being adjusted by a regulator. The water passes out without being in any way deteriorated, being simply raised in temperature by the heat abstracted from the gas. It is therefore available either for boiler feeding, quenching coke, or any other of the numerous requirements of a gasworks.

The influence of condensation on the illuminating power of coal-gas

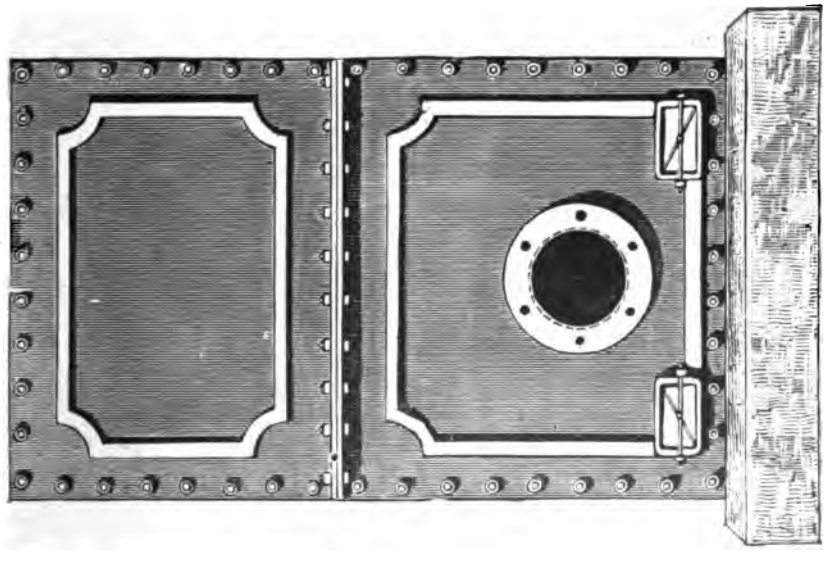
Digitized by Google

FIG. 60.



Battery Condenser.

FIG. 59.



Battery Condenser.

Digitized by Google

Digitized by Google

							11,048	14.80	15.15	163,510	167,377	7.50	12.65	0.292	14.41	150.00	1,698.0	24,468	948.9	13,673
4	Horizontal Condensing Main, in action[2]	1,758°	36°	135°	100°	44°	10,868	15.67	15.58	170,307	169,323	8.50	12.15	0.469	12.32	152.02	2,293.25	28,276	1,102.2	13,579
5	With Tar Extractor placed at South end of 8″ main[3]	1,731°	39°	136°	—	62°	10,980	15.92	15.89	174,801	174,472	8.25	12.91	—	14.48	—	—	—	—	—
6	Ditto	1,705°	42°	137°	about 128°	57°	10,786	14.67	15.56	158,231	167,830	8.14	13.98	0.562	14.11	139.54	1,787.4	25,220	731.7	10,324
7	With Tar Extractor, but placed at North end of 8″ main	—	45°	140°	about 132°	58°	11,091	14.85	15.41	164,701	170,912	9.09	13.80	0.459	14.17	156.72	1,956.23	27,719	912.7	12,933

* The amount of ammonia mentioned in this column is that produced by condensation *only*, and is irrespective of that obtained by subsequent processes.

NOTE.—The greatest difference in the quantity of CO_2 removed—viz., between Nos. 2 and 4—amounts to about 10 cubic feet per ton of coal, equalling in volume about .09 per cent. of the gas. The effect, therefore, of its removal upon the illuminating power cannot be appreciable.

1 Vertical condenser. This consisted of a series of pipes 8″ diameter, having a total length of 187 feet.

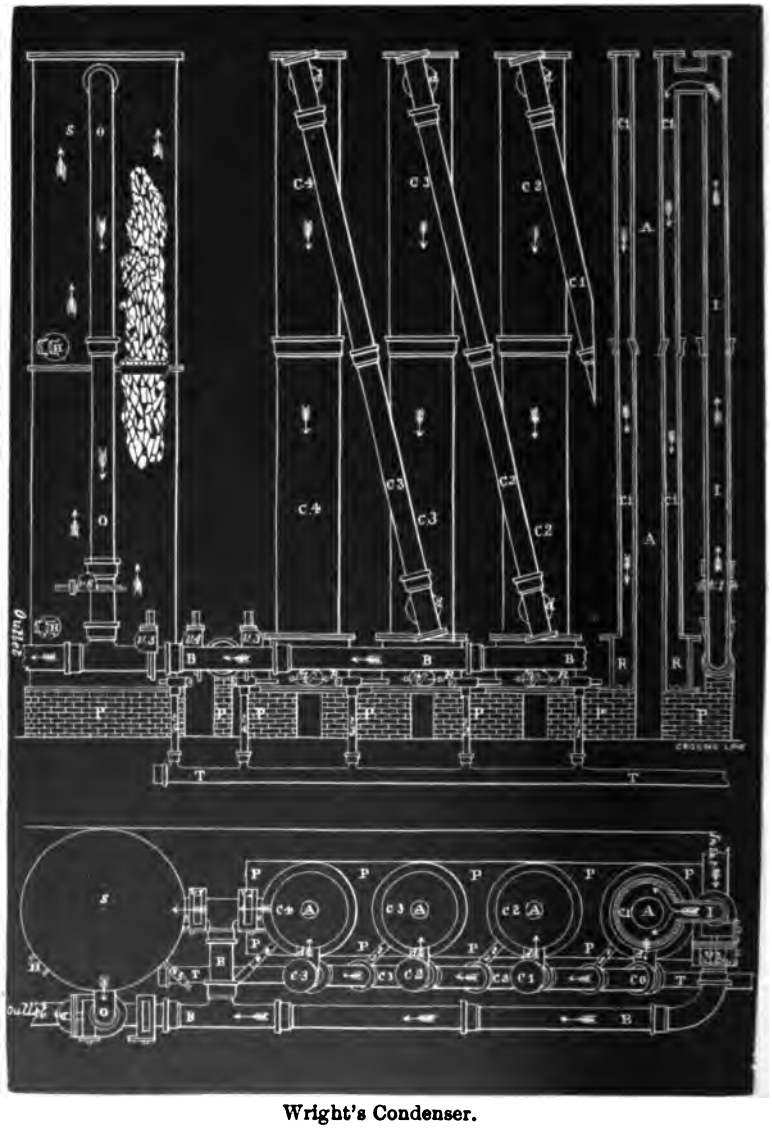
2 Horizontal condensing main. This was fixed along the side of the retort-house, the pipe being 10″ diameter, and its total length about 52 feet.

3 The 8″ main referred to was placed at the back of the hydraulic main, and used as a foul main.

Digitized by Google

was, during the years 1882 and 1883, made the subject of very careful and elaborate investigation by a Committee of the Council of the Gas Institute, assisted by Dr. Greville Williams, F.R.S., and Mr J. H. Martin. Under their directions a series of experiments on the subject was undertaken at the works of the Barnet District Gas and Water Company, the

FIG. 61.



Wright's Condenser.

results, together with the conclusions arrived at by the Committee, being published in the "Transactions of the Gas Institute for 1883," from which they have been extracted (see p. 73).

Commenting on this, the Report says: "The quoted averages of illuminating power given in this table are those obtained by means of the

Digitized by Google

No. of Experiment.	Description of Apparatus.	Average Temperatures. Fahr.					Cubic Feet of Gas produced per ton of Coal carbonised. Corrected to 60°.	Average Illum. Power of Gas. Methven's Standard.		Multiples. *i.e.*, Make × Illum. Power.		Tar produced per ton of Coal carbonised.		Oil in Tar per ton of Coal carbonised. Distilling over below 400°.	Liquor produced per ton of Coal carbonised.	* Ammonia in ozs. of Sulphuric Acid, per ton of Coal carbonised.	CO_2 in inches per gallon of Liquor	CO_2 in inches per ton of Coal carbonised.	H_2S in inches per gallon of Liquor.	H_2S in inches per ton of Coal carbonised
		Retorts.	Air.	Gas at exit of Hydraulic Main.	Gas at first point at which Tar was drawn off.	Gas at inlet of Exhauster.		Being made.	From Holder.	Being made.	From Holder.	Quantity drawn off at first point.	Total.							
												Gallons.	Gallons	Gallons.	Gallons.					
2	Vertical Condenser, thrown out . .	1,704°	40°	138°	122°	98°	10,972	15.50	16.38	170,175	179,721	7.70	11.05	0.192	10.95	106.65	1,111.5	12,172	829.0	9,077
3	Ordinary Plant, Vertical Condenser in action[1] .	1,706°	44°	142°	126°	68°	11,048	14.80	15.15	163,510	167,377	7.50	12.65	0.292	14.41	150.00	1,698.0	24,468	948.9	13,673
4	Horizontal Condensing Main, in action[2] .	1,758°	36°	135°	100°	44°	10,868	15.67	15.58	170,307	169,323	8.50	12.15	0.469	12.32	152.02	2,293.25	28,276	1,102.2	13,579
5	With Tar Extractor placed at South end of 8″ main[3] .	1,731°	39°	136°	—	62°	10,980	15.92	15.89	174,801	174,472	8.25	12.91	—	14.48	—	—	—	—	—
6	Ditto . . .	1,705°	42°	137°	about 128°	57°	10,786	14.67	15.56	158,231	167,830	8.14	13.98	0.562	14.11	139.54	1,787.4	25,220	731.7	10,324
7	With Tar Extractor, but placed at North end of 8″ main	—	45°	140°	about 132°	58°	11,091	14.85	15.41	164,701	170,912	9.09	13.80	0.459	14.17	156.72	1,956.23	27,719	912.7	12,933

* The amount of ammonia mentioned in this column is that produced by condensation *only*, and is irrespective of that obtained by subsequent processes.

NOTE.—The greatest difference in the quantity of CO_2 removed—viz., between Nos. 2 and 4—amounts to about 10 cubic feet per ton of coal, equalling in volume about .09 per cent. of the gas. The effect, therefore, of its removal upon the illuminating power cannot be appreciable.

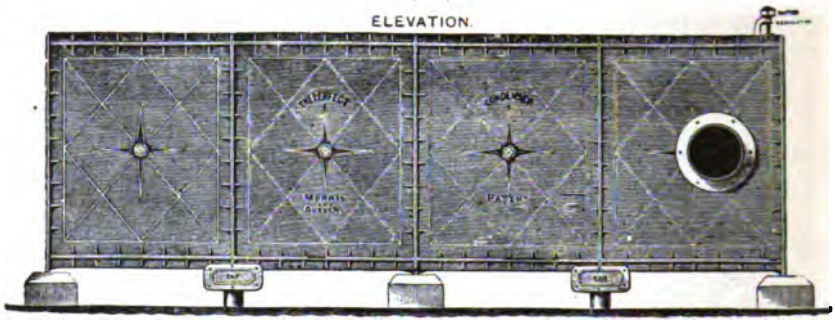
1 Vertical condenser. This consisted of a series of pipes 8″ diameter, having a total length of 187 feet.

2 Horizontal condensing main. This was fixed along the side of the retort-house, the pipe being 10″ diameter, and its total length about 52 feet.

3 The 8″ main referred to was placed at the back of the hydraulic main, and used as a foul main.

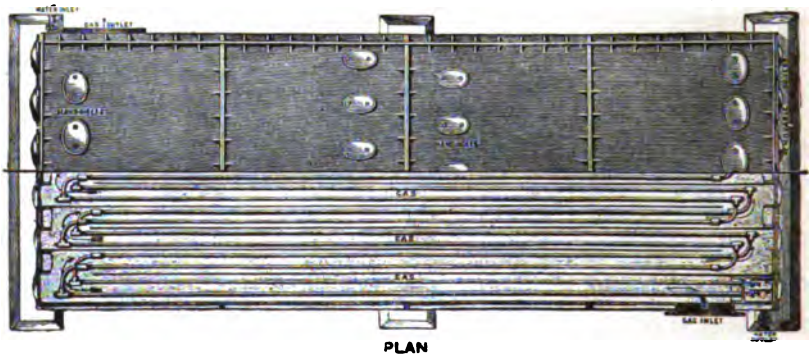
Digitized by Google

FIG. 62.



Morris and Cutler's "Perfect Condenser."

FIG. 63



Morris and Cutler's "Perfect Condenser."

FIG. 64.

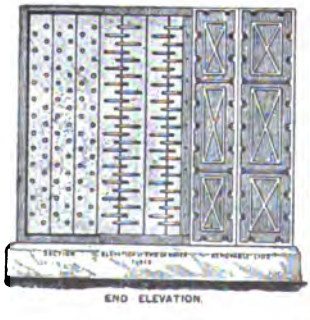
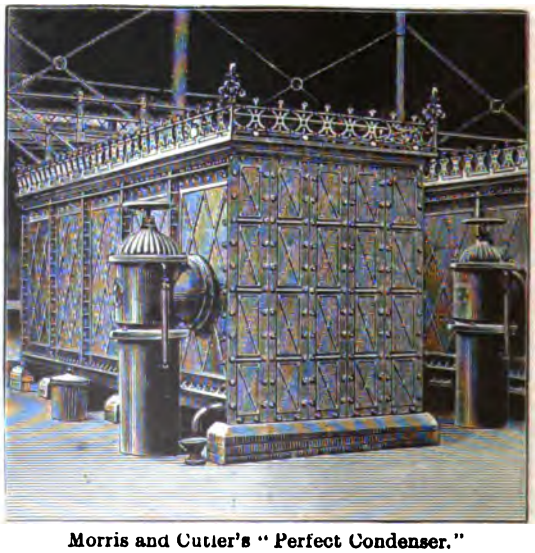


FIG. 65.



Morris and Cutler's "Perfect Condenser."

Digitized by Google

Methven standard, as representing the greatest number of observations; and experience has shown that the readings by it do not, on an average, differ materially from candle observations. Looking down the two columns of multiples, it will be seen that in the one relating to 'gas being made,' experiments Nos. 5 and 6 are contradictory, although conducted under precisely the same conditions; No. 6 being a repetition of No. 5. Omitting these, the best results appear in experiments Nos. 2 and 4, in the former of which condensation was imperfect, a large proportion of the lighter tar having been carried forward to the scrubber; while the lowest is afforded by No. 3, representing the works in their normal condition. On the whole, however, this column may be regarded as affording evidence in favour of prolonged contact with the lighter tar, the heavy tar having been previously removed. The other column, the one referring to 'gas from holder,' lends only a very faint support to such view. Here experiment No. 2 takes the lead, but is followed by No. 5, to which reference has already been made; and with regard to the others, no greater variations are apparent than usually occur in ordinary working. It is, in fact, evident that no opinion, based upon these returns taken in their entirety, can be expressed as to the superiority of any one of the systems of condensation which they represent, although it does not follow from this that they are the less conclusive. On the contrary, it cannot be without significance that, whereas throughout the whole of the experiments a very large proportion of the tar was separated from the gas while the temperature of the latter was still high—varying from 132° to 100°—the influence of subsequent contact with the lighter tar was so little marked as to be scarcely discernible; and the Committee are led by this to infer that, so long as the first deposit of tar is removed while the gas is at a comparatively high temperature, the form of condenser to be employed, whether vertical or horizontal, is very much a matter of indifference, and may without prejudice be determined by circumstances other than those relating to illuminating power."

CHAPTER IX.

Tar Extractors.

After leaving the condensers there is still a considerable quantity of tarry matter mechanically suspended in the gas, to remove which, either before or after passing through the exhauster, an apparatus designed by MM. Pélouze and Audouin, is much employed on the Continent. This is shown in Figs. 66 and 67.

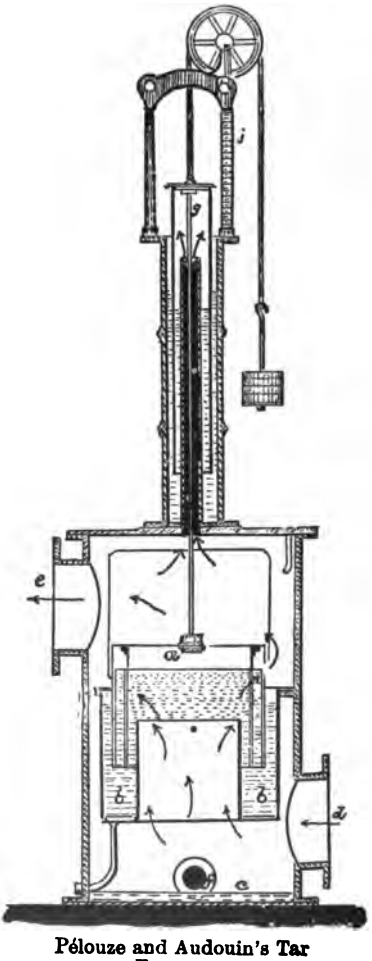
The gas enters the apparatus at the inlet *d* and passes into the perforated cylindrical vessel *a*, which is movable in the annular space *b*, where the separated tar collects. It then traverses the perforations in *a*, striking against the plain surface of the outer cylinder, which causes the separation of the tar. The gas eventually passes from the apparatus at *e*. By means of the governor *g*, the amount of surface of *a* exposed is regulated in proportion to the quantity of gas passing.

To separate the last traces of tarry matter, a scrubber is occasionally used, in England, filled with dry coke, through which the gas is drawn or forced, according to the position of the vessel in relation to the exhauster; the column of coke acts mechanically as a filter, and retains the greater portion of the tarry matter. The scrubber is cleaned by passing steam into it at intervals to remove the tar. A more effectual method, however, of cleansing the gas is the employment of a washer, either separate

Digitized by Google

from, or in combination with, the scrubber used for removing the ammonia. It is supplied with ammoniacal liquor, either by gravitation from the scrubber or condensers, or pumped up from the storage tank, and through this the gas is made to pass in minutely divided streams, with complete removal of the remainder of the tarry matter. Figs. 68 and 69 show the Livesey Washer, Fig. 68 being an end view of the apparatus, showing in section the longitudinal tubes of which it is composed. The gas enters

FIG. 66.

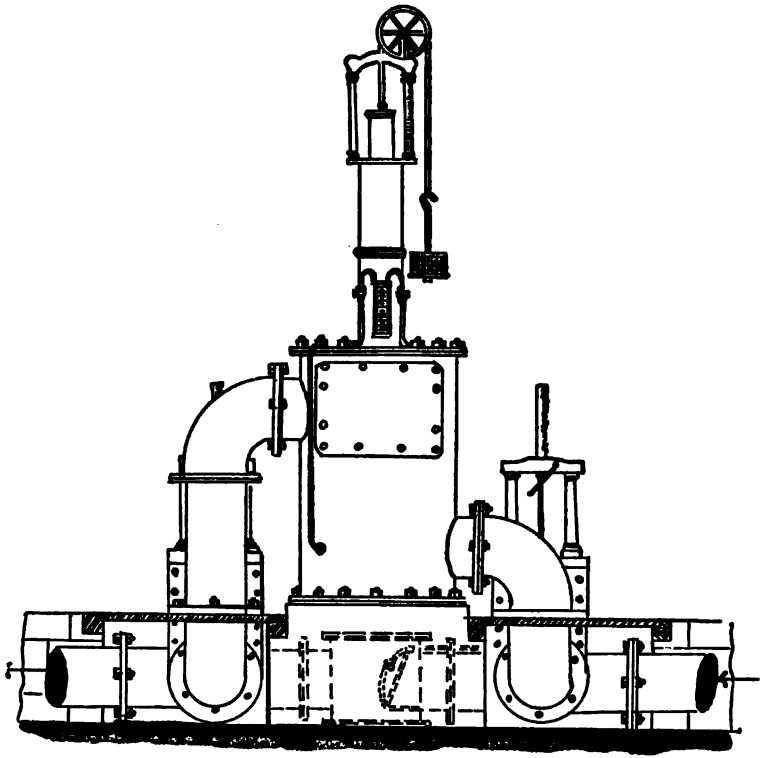


Pélouze and Audouin's Tar Extractor.

the gas-chamber at the top, and passes down between the longitudinal tubes to the water-line in the direction indicated by the arrow; then, depressing the water, the gas passes through the first perforated plate (which forms the lower and inclined part of both sides of the tubes) into the water within the bottom part of the tubes; then rises through the upper and horizontal perforated plate C, C, escaping in foam into the upper part of each covered tube at A, and, finally passing along to right and left, escapes at each

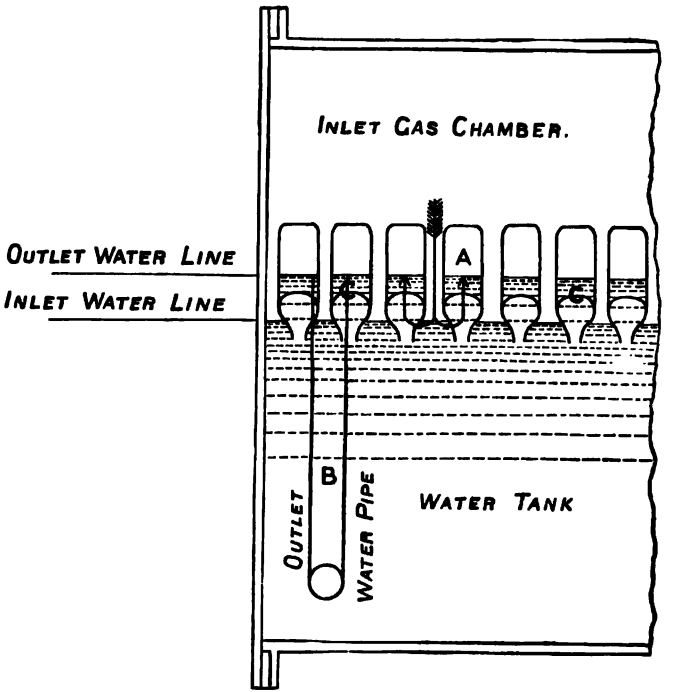
Digitized by Google

FIG. 67.



Pélouze and Audouin's Tar Extractor.

FIG. 68.



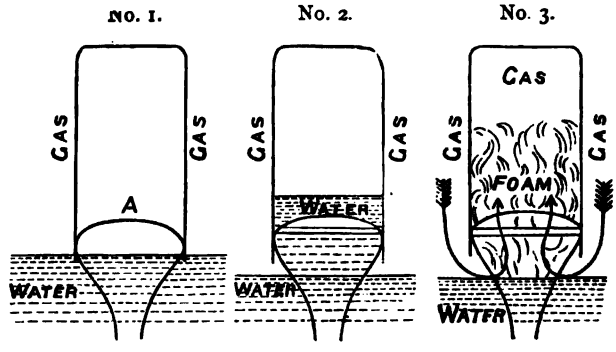
Livesey Washer.

Digitized by Google

of the open ends of the tubes. The passage of the gas produces a circulation of the water, which, rising through the perforated plates into the upper part of the covered tubes, rushes off (as the gas does) to either end of these longitudinal tubes, from which, while the gas goes upwards, it descends into the tank to resume the same course of circulation. An adjustable pipe B enables the depth of liquor to be altered to suit the quantity of gas which has to pass through it. The tar collects at the bottom of the vessel, and is drawn off at intervals by means of a syphon pipe.

To show the actual working of the apparatus, the diagrams, Fig. 69, are given, in which one of the longitudinal tubes is represented in section on a larger scale. No. 1 shows the tube when the apparatus is ready for work, but before the gas is admitted. No. 2 shows the tube just after the gas has been admitted, and has by its pressure lowered the water outside the tube and raised it within, but before the action has fully begun. No. 3 shows

FIG. 69.



Livesey Washer.

the tube when the apparatus is in full action. In addition to the almost complete removal of the tarry residue, this washer is very effective for the elimination of ammonia and other impurities, the amount being stated as follows:

	Cubic inches of impurities removed per 1000 cubic feet of gas.		
	H_2S.	CO_2.	Total.
No. 1 example	5688 ..	3574 ..	9262
„ 2 „	8675 ...	2122 ...	10,797

In some works, tar extractors are dispensed with, and these light tarry matters allowed to pass to the exhauster, where they act as a lubricant, being ultimately removed at the scrubber or washer (see Chap. XI.).

Digitized by Google

CHAPTER X.

Exhausters.

THE exhauster, as already stated, is for the purpose of withdrawing the gas from the retorts as quickly as it is produced, thus relieving them of pressure; and it likewise forces the gas through the purifiers and other

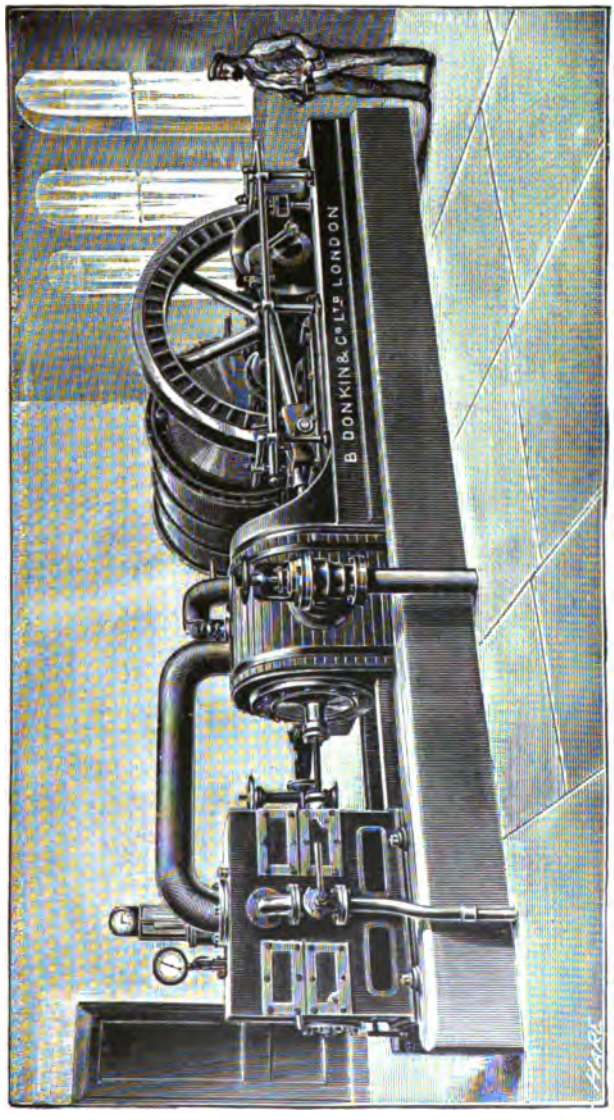
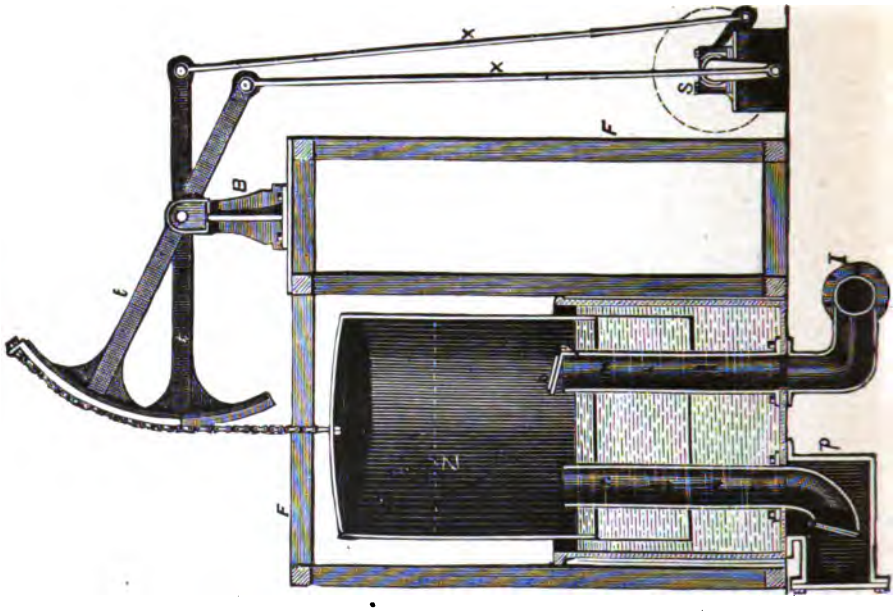


FIG. 70. Beale's Exhauster.

apparatus into the gasholders. The deposit of carbon within the retorts is thereby greatly reduced, and the loss of gas by leakage through them is so

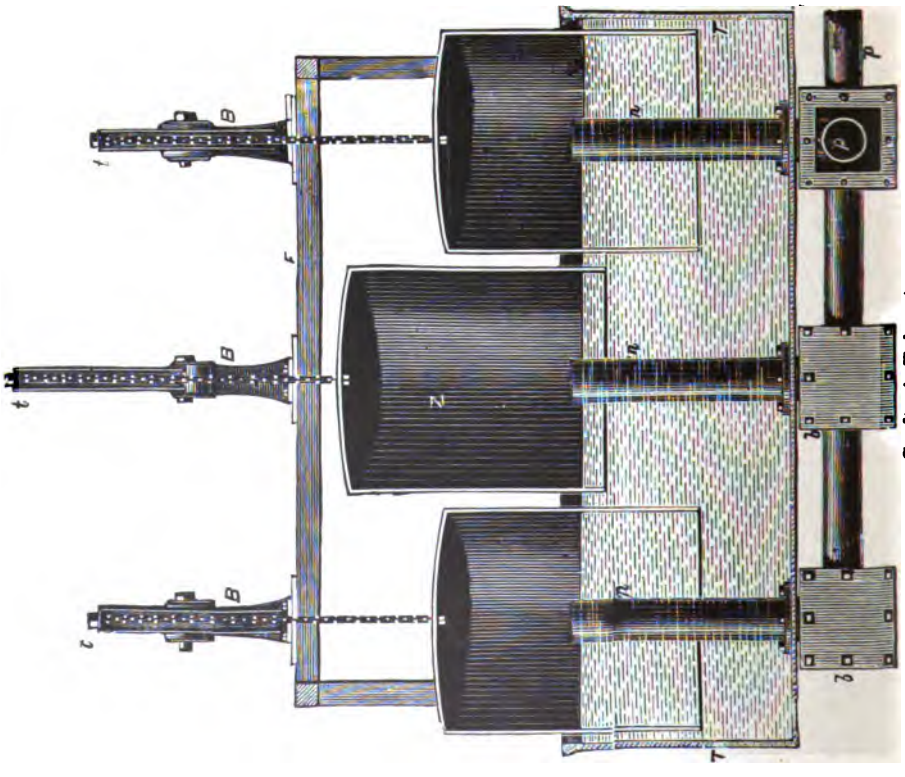
Digitized by Google

FIG. 72.



Grafton's Exhaustor.

FIG. 71.

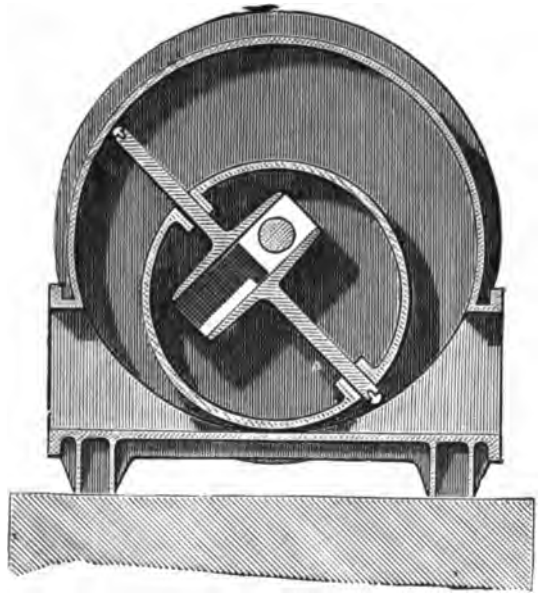


Grafton's Exhaustor.

Digitized by Google

much diminished as to render this apparatus indispensable for all, excepting the very smallest, works. One of the earliest forms of exhauster was that used by Grafton about the year 1840, and shown in Figs. 71 and 72 (p. 80). It consists of a cast-iron tank, having three inlet pipes, *m*, *m*, *m*, and three outlet pipes, *n*, *n*, *n*. The former are connected with the inlet main, and are provided at the top with clack valves, *o*, opening upwards, which prevent the retrogression of the gas. The outlet pipes are furnished with similar valves, *p*, but opening in the opposite direction. Three gasholders *Z Z Z*, are suspended one over each pair of inlet and outlet pipes, and work in the tar contained in the cast-iron tank. The chains by which these gasholders are suspended are attached to one end of the levers, *t t t*. These are supported at the centre by the brackets, *B B B*, resting upon the framework *F F F*, and are alternately raised and lowered by means of the rods *X X*, attached to the other ends, and which are worked by means of cranks placed at angles of 120° on the shaft *s*. On the shaft being rotated the gas is sucked into the gasholders from the inlet pipes to be afterwards expelled into the outlet pipes.

FIG. 73.



Beale's Exhauster.

The exhausters at present in use are of several kinds, those most generally employed being the reciprocating and the rotary; the former consisting of one or more cylinders and pistons arranged as double-acting pumps. A Beale's improved rotary exhauster is shown in Fig. 73; this is now largely used, either singly, or in pairs driven by one engine, an arrangement which is adopted for the purpose of avoiding oscillation in the pressure in the gas mains. Fig. 70 (p. 79) shows an exhauster driven by a horizontal condensing engine; gas engines are sometimes used for the same purpose.

Waller's three-and four-blade exhausters have been designed to reduce oscillation and friction. They ensure a steadier gauge, and require less power to drive them than the ordinary Beale exhauster; delivering with three-blades about one-third, and with four-blades about 40 per cent. more gas than the latter with the same sized cylinder, and at the same speed. The contents of the cylinder are discharged three and four times respectively in each revolution, against twice in the case of the Beale; the oscillation being proportionately reduced. The blades working on a central spindle are balanced, and are radial with the cylinder, working smoothly round its circumference without ring or segments instead of, as in the Beale, being eccentric to the cylinder.

The cylinder is a true circle with two branches, and either can be inlet

Digitized by Google

or outlet, but the direction for running is always from the inlet. The covers are recessed for the ends of the roller, and in the smaller sizes have a boss on one cover for a central hollow spindle, in large sizes the spindle goes through both covers. The central spindle is of steel, and hollow, to admit of oil being injected to lubricate the hinges of the blades. The roller is

FIG. 74.

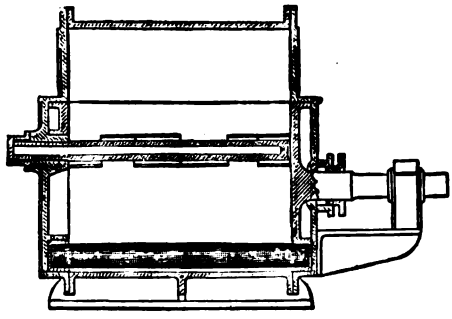


FIG. 75.

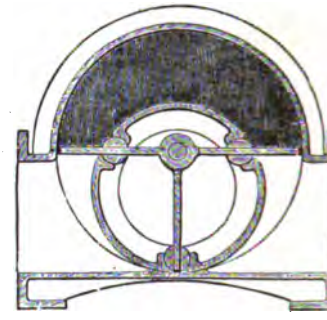


FIG. 76.

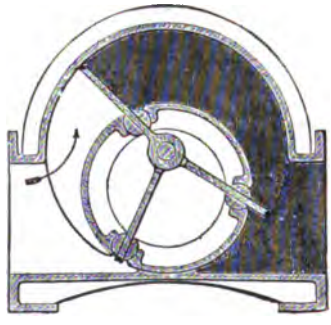


FIG. 77.

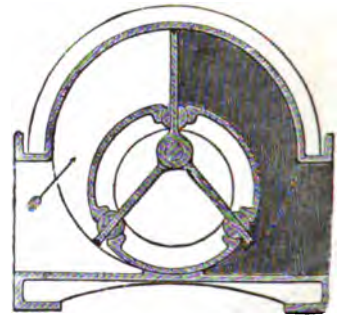


FIG. 78.

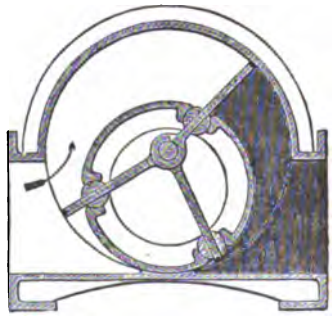
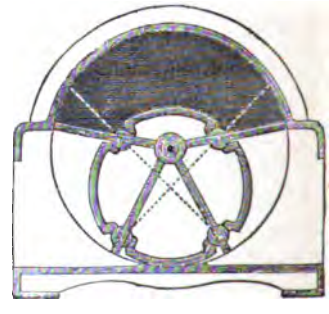


FIG. 79.



open at one end, and solid at the other (but in the large sizes open at each end); the ends fit in the covers, and round the circumference of the roller are slotted rollers to carry the blades and swivel with them to suit the varying position. Each blade has two hinges fitting between each other, making together a continuous bearing on the central hollow spindle.

Figs. 74, 75, 76, 77, and 78 show the action of the three-blade exhauster. Fig. 74 is a longitudinal section showing the arrangement of the central

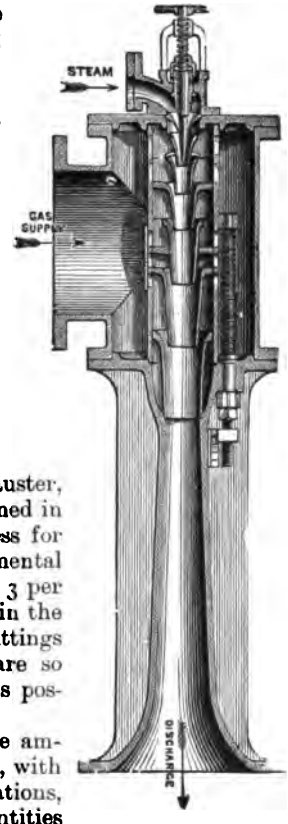
Digitized by Google

hollow spindle with the three blades hinged on it, and the main roller with one of the rolls at the bottom of it, through which the blades work. The four cross sections, 75, 76, 77, and 78, are intended to show the position of the blades during different periods of their revolution, and also show the position of the slotted rollers, which swivel to suit the varying angle of the slides. The dark space above the roller in Fig. 75 is cleared three times each revolution.

Fig. No. 79 shows the four-blade exhauster.

Another form, preferred by some engineers, is the steam jet introduced by Cleland and improved by Körting, by which exhaustion is effected without the medium of any moving parts; a jet of steam being admitted into the gas main through nozzles enclosed within it, Fig. 80. The apparatus is usually placed immediately after the condensers, but subsequent cooling of the gas is necessary.

FIG. 80.



Körting's Steam Jet Exhauster.

CHAPTER XI.

Washers and Scrubbers.

AT this stage, namely, at the outlet of the exhauster, the gas still contains all the ingredients mentioned in the table on p. 18. Several of these are useless for illumination, such as carbonic acid, which is detrimental to the illuminating power to the extent of about 3 per cent. for every one per cent. by volume present in the gas; ammonia, which acts injuriously on metal fittings and burners; whilst the sulphur compounds are so highly objectionable that their removal as far as possible is an absolute necessity.

The substances to be removed, therefore, are ammonia, carbonic acid, and sulphuretted hydrogen, with small quantities of sulphur in other combinations, together with compounds of cyanogen. The quantities of these present in coal gas necessarily vary with the nature of the coal employed in its manufacture.

Although scrubbers and washers fed with water are now almost universally employed for the removal of ammonia, it may be interesting to recall some of the early methods of dealing with this impurity. Pénot first suggested the sulphate of lead waste from the cotton print works as a means of removing ammonia; he suspended it in water in the manner of milk of lime. Sulphate of ammonia was produced on the one hand, and sulphide of lead on the other; but the sulphate of lead could not be obtained in sufficient quantity nor was it sufficiently cheap for use in the gasworks. Chloride of lead was also recommended by Loth to be used on the shelves of a dry lime-purifier. Another substance for purification, first proposed by Mallet, was sulphate of manganese, formerly produced in abundance in the bleaching powder works; green vitriol, or sulphate of iron, has also been employed. In using any of these salts, as well for the preservation of the vessels as for obtaining the proper action, it was recommended to neutralise the excess of acid contained in them by the ammoniacal water of the tar cistern. The gas was often brought into contact with the solutions in the form of a shower, producing a pressure of not more than

Digitized by Google

100 gallons of water, up to the level of this plate, below which the gas was introduced and distributed through the various compartments.

The gas being thus brought into intimate contact with the acid, the latter was quickly saturated, a fresh supply of it then being furnished from a reservoir placed at a higher level. Two or three of these vessels used consecutively could purify 500,000 cubic feet of gas every twenty-four hours, and required re-charging with acid about every second day. The liquor thus obtained yielded 80 ounces of sulphate of ammonia for every gallon that was evaporated, instead of 14 ounces, which was the average quantity obtained from the ordinary ammoniacal liquor of the condensers.

Chlorides and sulphates of manganese, iron, or zinc, have also been proposed instead of sulphuric acid; the compounds formed from these salts to be again decomposed, and the products re-applied in the purifying process.

Three cylindrical vessels, Plate II., A B C, on different levels, were formerly used. The metallic solution, or milk of lime, was brought by the pump *f* to the pipe *g*, which conveyed it into the vessel C. A water lute pipe *h* permitted the excess to flow through the tube *g'* into the second vessel B, and by a similar contrivance into the third A, and thence into the tank K. The gas passed in the contrary direction, by the pipe *a a* into the cylinder A, where it was washed by the purifying liquid, and thence through the other cylinders to the ordinary dry lime-purifiers.

The agitators *i i' i''* were kept moving slowly by means of belts, or occasionally by handles, in order to prevent the insoluble sulphides and carbonates from accumulating at the bottom, as well as to present a new surface to act on the gas. When this precipitate increased in quantity, it could be removed by the cock *j'*.

The whole contents were collected in the tank K, and the clear liquor was run off into another cistern M, whence the ammoniacal liquor was pumped by means of *f* into suitable evaporators.

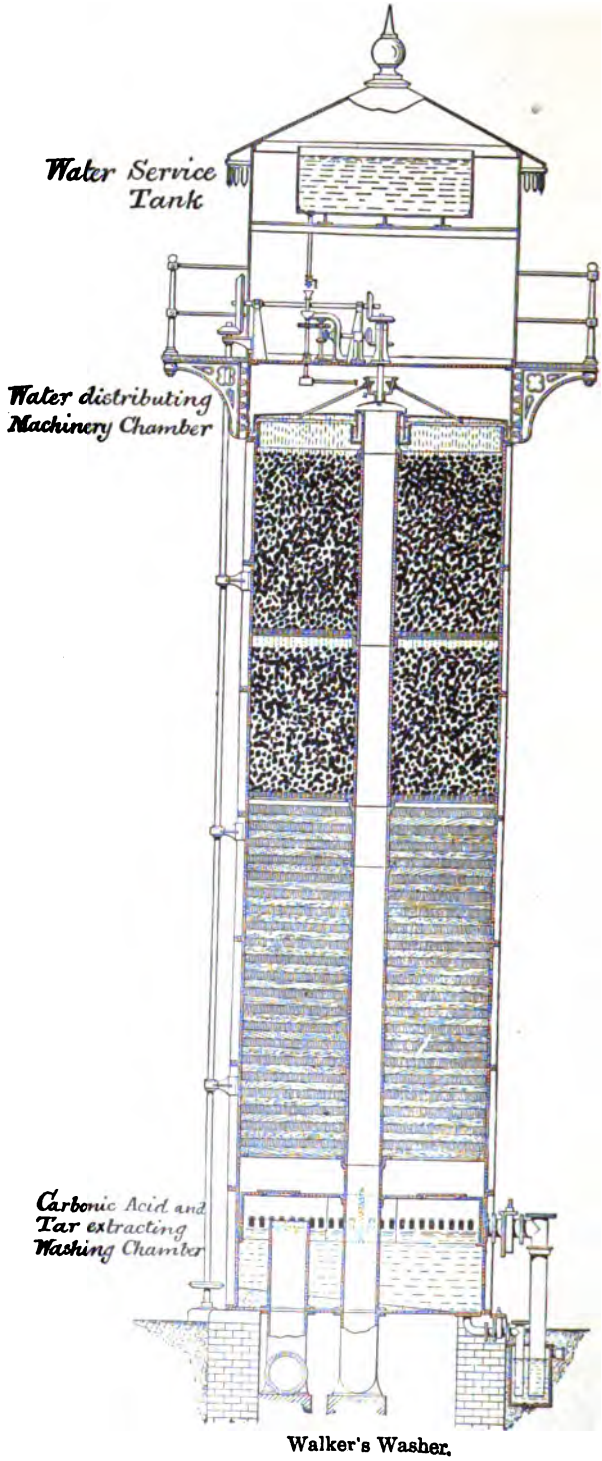
Absorbents employed in a moist but not wet condition in the dry lime-purifiers, subsequently received the preference for removing the sulphuretted hydrogen. The salts of iron, manganese, zinc, and nickel, employed in this manner, absorb ammonia and an equivalent quantity of the sulphuretted hydrogen; but they allow the greater part of the sulphuretted hydrogen to escape. The salts of lead, bismuth, tin, and antimony, absorb the whole of the sulphuretted hydrogen, but their cost generally prevented their application. The oxides, either hydrated or anhydrous, of manganese, iron, zinc, lead, copper, and antimony, have all been made the subject of patents, and the oxides of iron, lead, and antimony, have been employed in this country. Croll, by a patent dated 1840, appears to have been the first to secure the right of employing the oxides of manganese, zinc, and iron, in a moist condition, placed in a dry purifier, for separating sulphuretted hydrogen from gas after the ammonia had been removed by chloride of manganese, or some similar metallic salt.

Marriott's process consisted in saturating wood sawdust with weak sulphuric acid and heating to dryness—the sawdust being placed in layers in purifiers through which the gas was passed. At the Birmingham Gas-works, Wrightson employed in a similar manner sulphate of iron and superphosphates; the use of the latter was subsequently revived by Bolton and Wanklyn.

The scrubber is usually a cylindrical cast or wrought iron vessel, of a diameter varying according to the quantity of gas to be passed through it, and frequently from 40 to 70 feet in height, and is filled with coke, or with thin boards placed edgewise. When coke is used, this is disposed upon a series of trays placed one above the other at a distance of from six to ten feet

Digitized by Google

FIG. 82.



Walker's Washer.

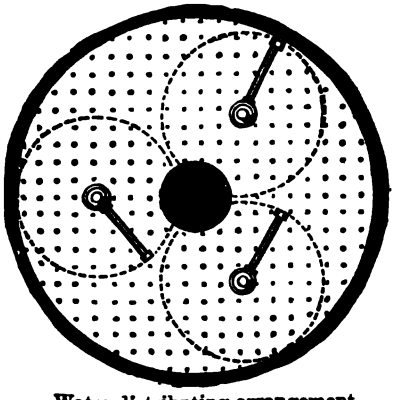
Digitized by Google

Digitized by Google

Digitized by Google

apart, over the uppermost one of which clean water is distributed; this in its descent meets the foul gas, which enters the scrubber at the bottom, and passes out at the top, usually by means of an outlet pipe placed in the centre of the scrubber. The object of this arrangement is to present constantly a freshly wetted surface to the gas, the clean water introduced at the top becoming in its passage through the scrubber converted into strong ammoniacal liquor by its gradual absorption of ammoniacal compounds. Mann greatly improved the scrubber by applying motive power for the distribution of the water, and by his application of revolving brushwood distributors. Other improvements were subsequently introduced by him, in conjunction with Messrs. C. and W. Walker. In order to get an even distribution of water in the scrubber, it is run from an overhead tank into three funnels—one of which is shown in Fig. 82—attached to the ends of three vertical pipes, the other ends of which are sealed in small chambers by water. From these chambers the water passes by an overflow pipe into the interior of the scrubber, where it is discharged at the

FIG. 83.



Water distributing arrangement.

FIG. 84.

Walker's Washer.

ends of the revolving arms shown in Figs. 82 and 83. By an arrangement of eccentric wheels, these arms are made to revolve much more slowly when they are discharging water away from the centre of the scrubber, and thus an even distribution is achieved. This results in a smaller quantity of water being used to clean the gas, and consequently in a stronger liquor being obtained.

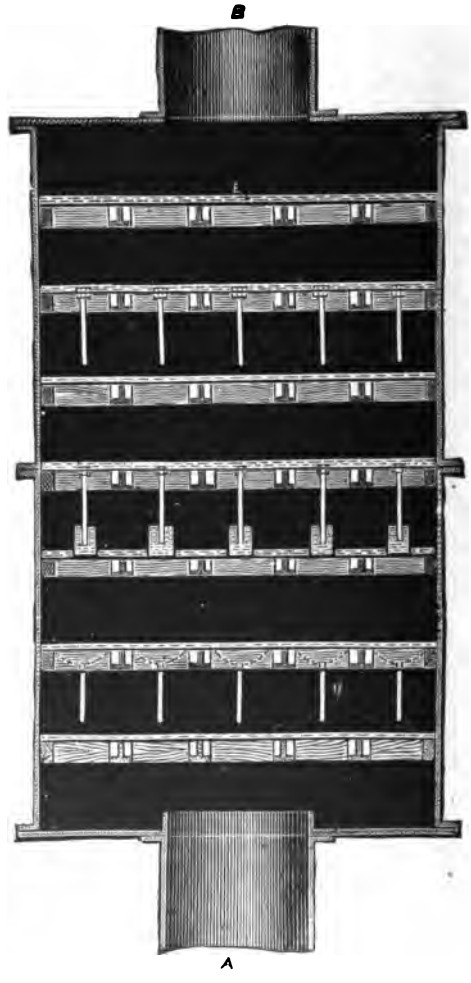
Experience having proved the desirability of removing all tarry matter from the gas before its entry into the scrubber, Messrs. C. and W. Walker, in the year 1881, patented a washing chamber which was placed in the lower part of the scrubber; into this the crude gas first enters, and is there completely deprived of all tar, together with a large portion of the carbonic acid, by the strong fresh ammoniacal liquor constantly descending from the scrubber. In addition, they subsequently substituted thin boards for coke in the lower half of the scrubber, and in place of the revolving brushwood for distributing the water, a perforated metal plate was employed. Figs. 82, 83, and 84 show a Walker scrubber as now constructed. The revolving sealed spreading plate, shown on plan in Fig. 83, travels in the opposite direction to the eccentrically moving arms which supply it with water. It is found that the holes in the metal, if it is thin enough, do not become choked; the deposits from the gas get no hold of the metal, but are blown out by the force of the current. This arrangement is found to possess great

Digitized by Google

advantages over that in which brushwood is used, owing to its being less liable to become choked with carbonaceous deposits when very high heats are employed.

Fig. 84 shows a plan of the washing chamber, which consists of a series of troughs, each formed by bending a thin sheet of metal into

FIG. 85.



Livesey's Scrubber.

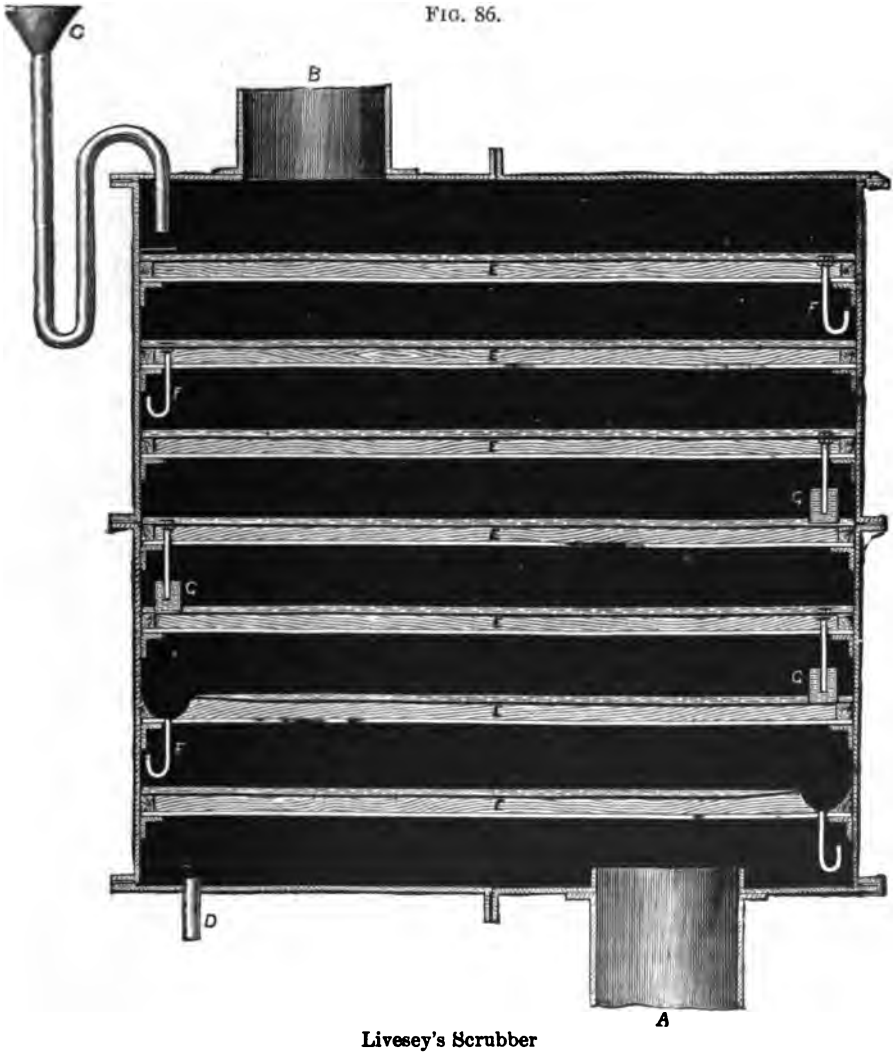
an inverted trough-shape and making a series of slots or perforations in the lower part of the sides thereof—the extreme or outer end of the trough being closed, whilst the other end is attached to the side of a chamber in which the gas to be purified is received. These inverted troughs are arranged in any required number at suitable distances apart in the tank shown, in such a manner that their lowermost portion in which the slots are formed shall be immersed in the liquor contained in the tank. The crude gas which is conveyed by the inlet pipe into the inverted troughs, escapes from them, into the upper part of the tank, through the slots or

Digitized by Google

perforations of the submerged portion of the troughs in both directions, and in this way the tarry matters are removed from the gas. It is stated that by these improvements the efficiency of the scrubber has been increased by fully 50 per cent.

The use of thin boards, about ¼ in. thick, in place of coke was intro-

FIG. 86.



Livesey's Scrubber

duced by Mr. G. T. Livesey in the year 1866, and since that time it has been widely adopted.

Mr. Livesey has calculated the amount of surface exposed by the undermentioned materials per cubic foot occupied :—

Coke gives about	8½	square feet of surface.
3-inch drain-pipes	17	,, ,,
2-inch ,, ,,	21	,, ,,
Boards as described	31	,,

Digitized by Google

Coke occupies	½	the cubical contents.	
3-inch drain-pipes	⅛	„	„
2-inch „ „	⅛	„	„
¼ inch boards placed 1 inch apart centres	¼	„	„

About the same time Mr. Warner had a similar scrubber constructed; but he placed the boards obliquely to one another, and dispensed with the usual spreader, substituting a series of troughs, from which the water overflowed.

Although the first cost of filling the scrubber with boards is much greater than with coke, it is to be preferred on account of its larger surface area for gas contact, and the smaller space occupied by the material, which permits of a diminished speed in the flow of the gas. It has the further advantages of securing immunity from obstruction while the scrubber is in action, and of saving labour in the periodical emptying and refilling the vessel.

Vessels with the object of removing the whole of the ammonia without the aid of coke, thin boards, or other distributing medium have been invented by Livesey, Anderson, Cathels, Saville and others. Livesey's scrubber is shown in Figs. 85 and 86 (pp. 88 and 89). It consists of a rectangular cast-iron vessel, provided with a number of carefully levelled, finely perforated trays E E. Water is admitted at the top through the syphon C, and flows from tray to tray by means of either the bent tubes F or the tube and seal-pots G. These tubes are so adjusted as to maintain about ½ inch of water on the trays when the gas is passing.

Gas passes into the vessel by the pipe A, then through the holes in the trays, thus being brought into intimate contact with the water, and finally away by the pipe B. So long as the apparatus is at work the water does not pass through the perforations.

Mention has also been made of the Livesey Washer, under the head of Tar Extractors (p. 76). This, however, is not only useful in cleansing the gas from the remaining traces of tarry matter; but if kept constantly supplied with the unsaturated liquor from the hydraulic main, also removes a large proportion of the gaseous impurities.

A modification of the apparatus known as "Coffey's Still," has likewise been used with good effect for the elimination of ammonia by Mr. J. Eldridge and Mr. H. E. Jones.

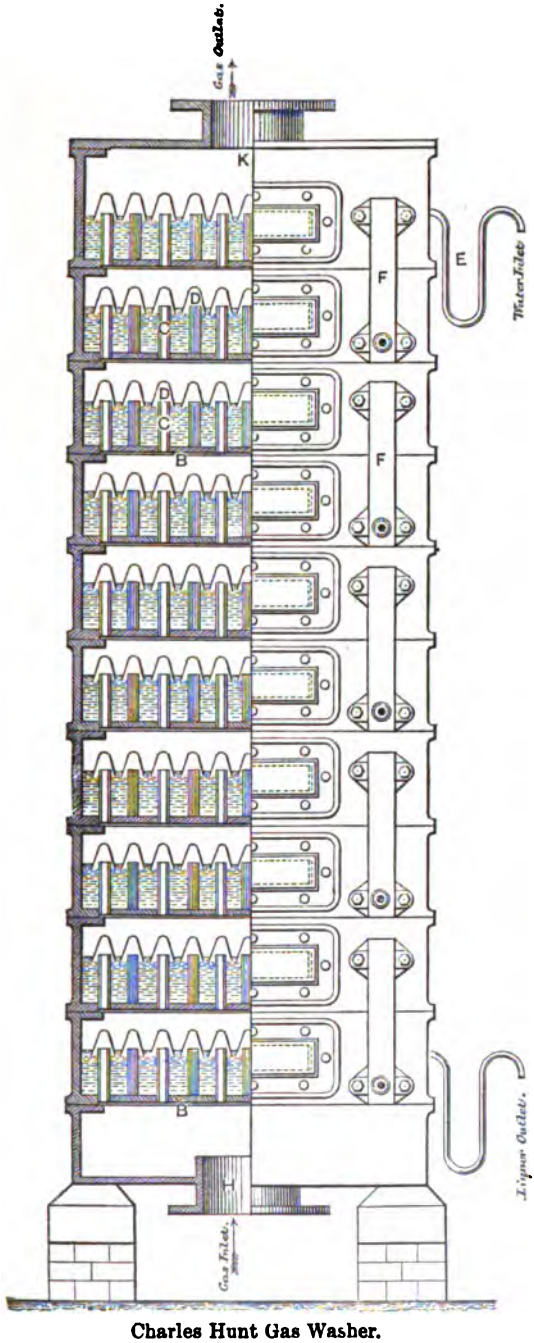
A new form of washer, Figs. 87 and 88 (pp. 91 and 92), called the Charles Hunt Gas Washer, is of more recent introduction. It is divided by horizontal partitions B, into a number of compartments, in each of which water is maintained at a constant level. Through each partition tubes C, arranged in rows pass upwards to a height a little above the water level in the compartment above, and over each row of these tubes, which are open at the top, is placed a hood D, in the form of an inverted trough having its edges perforated with numerous small holes, which, when the trough is in position, are immersed in water. The uppermost compartment being supplied with water through the syphon E, and each of the compartments below being supplied by an overflow F from that above it, gas, admitted at H, passes up the tubes into the hoods, and, passing through the small holes, bubbles up through the water into the space above the water in the lowest compartment, thence it passes through the next set of tubes and hoods, and so on from compartment to compartment until it issues from the uppermost compartment K free from ammonia, whilst the liquid overflowing from the lowest compartment is in the form of strong ammoniacal liquor.

This apparatus not only removes all trace of ammonia from the gas, together with a high percentage of the carbonic acid and sulphuretted hydrogen in combination with it, but also any tarry matter remaining in

Digitized by Google

the gas after its passage through the condensers. No separate apparatus for the extraction of tarry matters is therefore required.

FIG. 87.

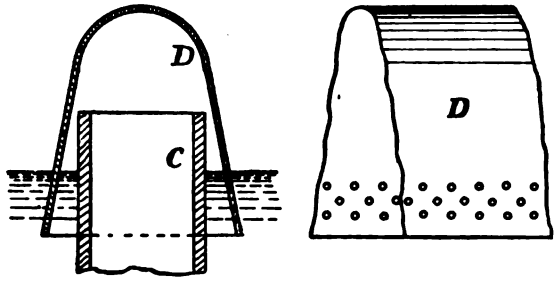


Charles Hunt Gas Washer.

Digitized by Google

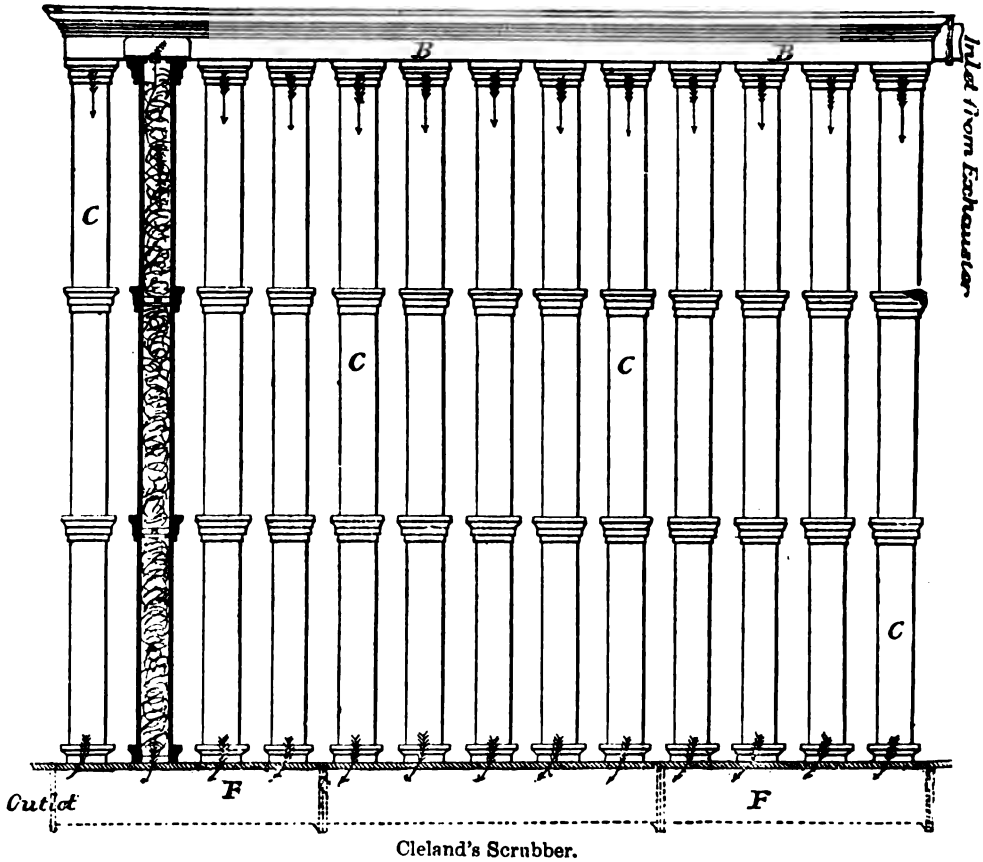
It is claimed as a further advantage for this apparatus that it requires no special driving machinery, and that there are consequently no wearing parts.

FIG. 88.



Charles Hunt Gas Washer.

FIG. 89.



Cleland's Scrubber.

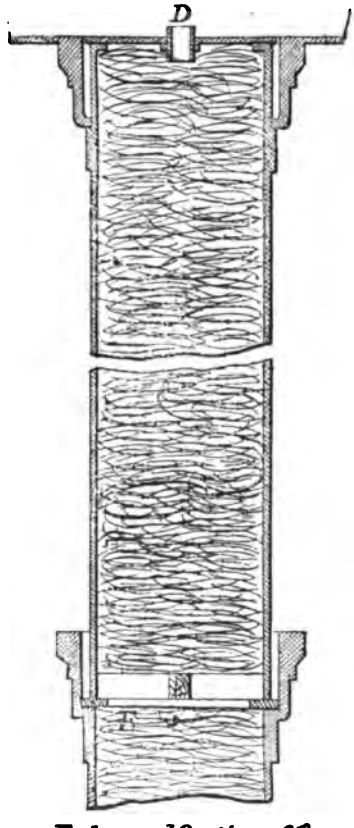
To overcome the pressure caused by the water seals, a slight additional duty is thrown on the exhausting machinery. amounting only to about ¾ h.p. per million cubic feet, which represents considerably less than the power needed

Digitized by Google

to drive a rotary washer. This additional work is, moreover, proportionate to the quantity of gas produced; whereas the power expended in the case of a rotary washer remains practically constant, although the production may vary.

In conjunction with the steam jet exhauster, already described, Mr Cleland has devised a simple and effective form of scrubber in which the steam, which has to be removed by condensation, is used for extracting the ammonia and other impurities. Fig. 89 shows the arrangement which consists of a series of vertical pipes filled with slightly compressed stiff shavings of pine wood, supported by crosses of timber at the joints. Drip rings *E* are placed at the joints so as to prevent the water from simply passing down the surface of the pipes. *B* is the inlet main from exhauster; *F* the outlet main from the apparatus. As the inlet and outlet are thus placed on opposite sides of the apparatus, and the pipes *C* are, moreover, fitted with adjustable throttle pipes *D*, Fig. 90, an equal distance in travel is provided, thus ensuring the passage of equal streams of gas, &c., through the pipes *C*. The steam is condensed in these pipes, and the water, with the absorbed ammonia, trickles through the shavings, and passes from the apparatus by the main *F*.

FIG. 90.



Enlarged Section of C.

For the complete elimination of ammonia by any scrubbing or washing apparatus either height, or a series of seals (by which the back pressure is greatly increased), is indispensable, because necessary for graduating the strength of the liquor, and terminating the process with clean water. The same effect, however, is also obtained by what is known as a scrubber-washer. This is sometimes arranged vertically like Anderson's, which consists of a series of circular brushes, placed one above another and caused to revolve in opposite directions, and always in the opposite direction to the flow of gas, but more generally, the horizontal form is employed, the apparatus consisting of a number of chambers, from one to the other of which the water or liquor flows in a direction contrary to that of the gas; the clean water introduced at the gas-outlet end leaves at the opposite, or gas-inlet end, highly charged with ammonia and other impurities.

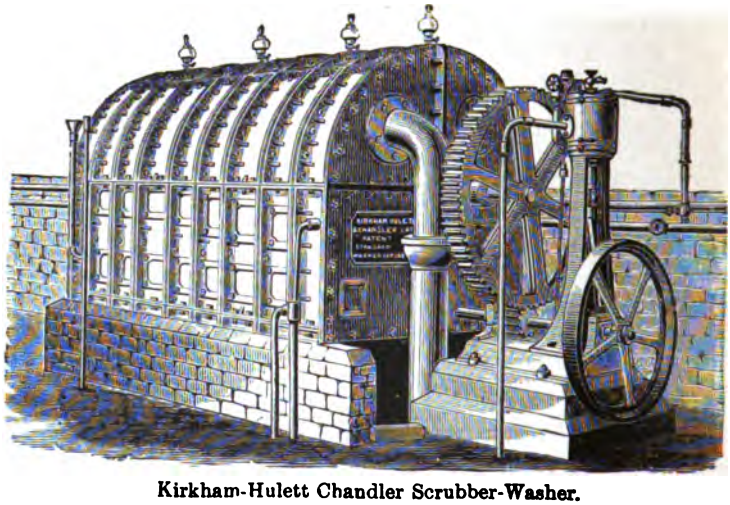
Paddon's Scrubber-washer consists of a tank containing a number of perforated plates half immersed in water, which, when revolved, present a continually fresh-wetted surface to the gas passing through the apparatus. Three of these vessels are used, so placed that the liquor can gravitate from one to the other. The foul gas, of course, first enters the lowest of the three, and passes from the highest, which is supplied with clean water.

Digitized by Google

Fig. 91 shows a Kirkham, Hulett and Chandler scrubber-washer; in which circular discs of thin metal fastened together at distances of about ¼ inch apart, are secured to a shaft which passes out through the end of the apparatus, and is caused to revolve at a speed of about five revolutions per minute. The lower half of the discs being immersed in the water or liquor which fills each chamber, every revolution of the shaft causes a freshly wetted surface to be exposed to contact with the gas passing through the apparatus in the direction of the arms.

Objection having been taken to the great weight of the metal discs, which, made up in segments, are known as "bundles," the washing surfaces of this apparatus are now formed of wooden laths arranged as shown in Fig. 92.

FIG. 91.



Kirkham-Hulett Chandler Scrubber-Washer.

The laths are kept in position by being passed through slotted iron sheets, and are then enclosed with plain sheets, bolted together and to the frame as shown. It is claimed that by thus substituting wood for iron, the driving shaft of the apparatus is relieved of five-sixths of the weight, and consequently the driving power and wear and tear are greatly reduced.

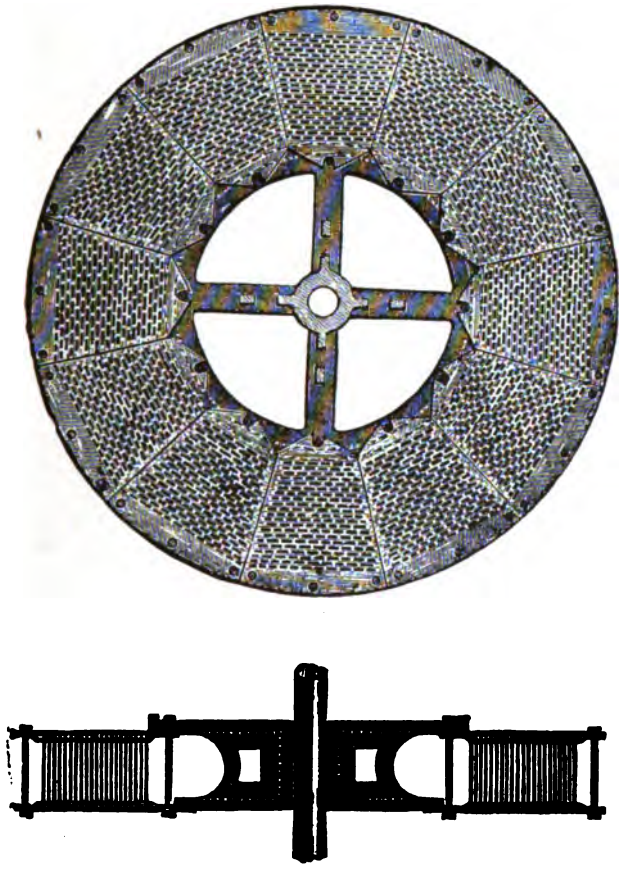
C. and W. Walker's patent purifying machine is shown in Fig. 93 (p. 96). This is stated to be a powerful and compact apparatus for the removal of ammonia, along with a considerable proportion of the carbonic acid. The gas, passing upwards through a series of superposed chambers, comes into contact in each with a very large area of freshly wetted surface. This is obtained by means of thin boards, secured edgewise to a frame, and alternately dipping into, and rising out of, the liquid in the chamber. Comparatively little power is required to drive the machine, which completely cleanses the gas of any tar left in it after condensation.

To estimate the quantity of ammonia in the gas at the entrance of the washers and scrubbers, the gas should be passed through (1) a U-tube containing a plug of cotton-wool to retain tarry matters; (2) a "Referee's ammonia cylinder," Fig. 124 (p. 145), filled with glass beads, and into which 25 c.c. of normal sulphuric acid has been run; and (3) an experimental meter for determining the quantity of gas passed, which should be about 1 cubic foot. After the gas has passed, the ammonia cylinder is well washed out into a porcelain dish and the excess of acid determined with normal

Digitized by Google

caustic potash solution, using one drop of methyl-orange solution (strength, 1 gram in a litre of water) as an indicator. Each c.c. of the normal acid neutralised by the ammonia in the 1 cubic foot of gas passed represents $0.017 \times 15.43 \times 100 = 26.23$ grains of NH_3 per 100 cubic feet of gas.

FIG. 92.



Discs of Kirkham-Hulett-Chandler Scrubber-Washer.

After passing through the washers or scrubbers the gas should be quite free from ammonia, and consequently moistened turmeric paper should not be reddened if held in a stream of the gas.

If traces of ammonia are present, the quantity may be ascertained by passing about 10 cubic feet of the gas through the ammonia cylinder, which should now contain 25 c.c. of deci-normal sulphuric acid.

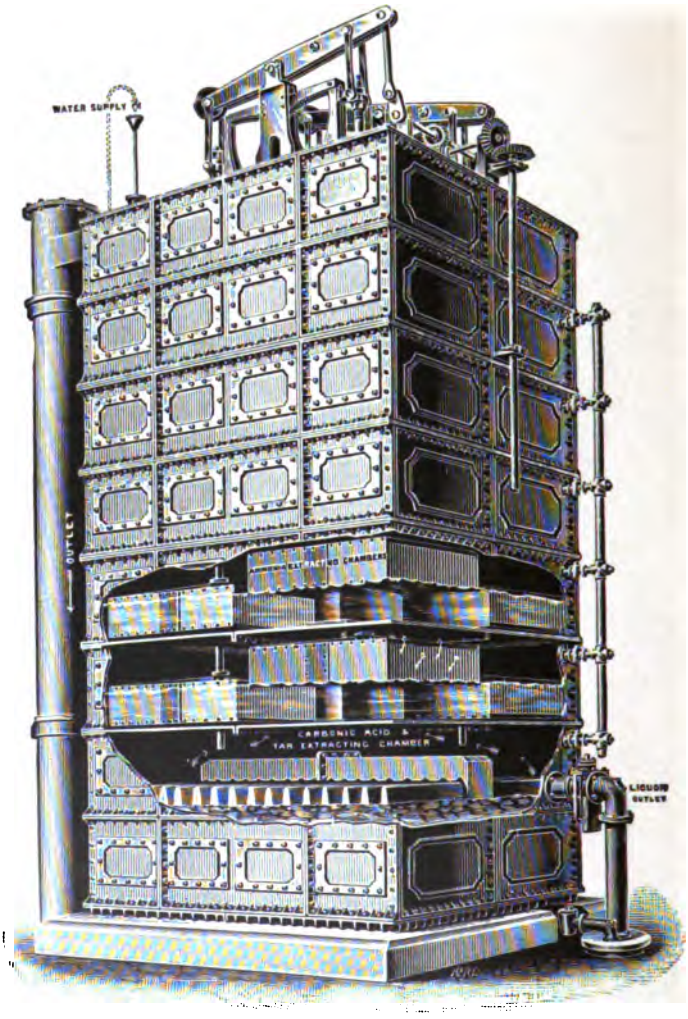
Each c.c. of acid neutralised represents $0.0017 \times 15.43 \times 10 = 0.2623$ grains of NH_3 per 100 cubic feet of gas.

Ammoniacal liquor plays a very important part in the process of purification, for in combination with ammonia a large proportion of the impurities —carbonic acid and sulphuretted hydrogen—are removed, and the cost of the subsequent purification is consequently lessened. It is therefore desirable to ascertain to what extent this is being done; and if it be found that

Digitized by Google

the ammonia is not removing a proper proportion of the impurities, to devise means for remedying this defect. In order to do this it is necessary to estimate the amount of what is known as "volatile" ammonia, and also the amount of carbonic acid and sulphuretted hydrogen in the liquor.

FIG. 93.



Walker's Purifying Machine.

Volatile Ammonia.—The amount of this is determined by means of the "saturation" test described on page 98.

Carbonic acid.—By means of a pipette 50 c.c. of the liquor is transferred to a flask, and excess of a clear solution of calcium chloride, to which a little strong ammonia has previously been added, is run in. The flask, with its mouth covered by a watch-glass, is now placed in a water bath and heated dor about two hours. The precipitate of calcium carbonate is washed by fecantation with boiling water containing a drop or two of ammonia until

Digitized by Google

free from chlorine, the washings being passed through a moistened filter which should be kept covered as much as possible with a large watch-glass to prevent absorption of carbonic acid from the air. The precipitate is then washed with plain boiling water until free from ammonia, and the filter with its contents is put into the flask, which should retain the bulk of the precipitate. A drop or two of methyl orange is added, and then an excess of normal hydrochloric acid. After the carbonic acid has been completely driven off the excess of acid is determined with normal caustic potash solution.

Each c.c. of normal acid corresponds with 0.022 gram of CO_2.

Sulphuretted Hydrogen.—50 c.c. of the liquor is put into a beaker, and excess of a solution of zinc sulphate and ammonium chloride added. The whole is well stirred, and the precipitate collected and well washed. Then by means of a stirring rod the precipitate is removed in very small portions at a time, each of which is plunged into strong bromine water acidified with hydrochloric acid, and contained in a beaker. When the precipitate has been thus removed as far as possible, the beaker is placed underneath the funnel, a hole made in the filter paper with a glass rod, and the remainder of the precipitate is washed into the acidified bromine water. The bromine is boiled off, the solution filtered, and the sulphuric acid present determined by precipitation with barium chloride. See p. 147.

Each gram of $BaSO_4$ = 0.146 gram of SH_2.

If it be supposed that as the result of such analysis the figures given on p. 106 for Stafford gas liquor be obtained, then division by the combining equivalent in each case gives the required information.

Volatile ammonia . .	1.85 ÷ 17 =		109
Sulphuretted hydrogen .	0.82 ÷ 17 =	48	
Carbonic acid . .	3.17 ÷ 22 =	144	192
Excess acid equivalents		=	83 or 76 per cent.

In the case of bi-compounds of ammonia there are, of course, twice as many acid equivalents as ammonia equivalents in combination; but under the conditions obtaining in the production of ammoniacal liquor the ammonia cannot be so completely utilised. In the liquor mentioned above, there are 76 per cent. more acid equivalents than are required to form mono-compounds with ammonia, which is a very high figure. Should an excess of from 30 to 50 per cent. be obtained, the ammonia is being very satisfactorily utilised.

CHAPTER XII.

Ammoniacal Liquor.

THE quantity of ammoniacal liquor obtained per ton of coal carbonised varies from 25 gallons of 10 oz. strength to 40 gallons and even more, according to the capabilities of the coal used for producing ammonia, the temperature of carbonisation, and the care taken in thoroughly extracting it from the gas, and in storing the ammoniacal liquor. About one-half of this quantity is usually yielded as "virgin" liquor, that is, water condensed from the gas during the process of cooling, accompanied by a portion of the ammonia and other impurities; the remainder being obtained by means of the water used in the washers and scrubbers. The researches of the late Prof. W. Foster and others have proved that neither high nor low temperatures are favourable to the production of ammonia; this being obtained in greatest quantity at a moderate heat, say, 1700° F.

Digitized by Google

Experiments made by Messrs. Ramsay and Young * show that the temperature at which ammonia gas begins to decompose, lies a little below 500° C. (932° F.). It is therefore readily conceivable that after the ammonia has been formed during distillation of the coal, there is great risk of its decomposition by exposure to the heat which is radiated from the sides of the retort.

Valuation of Ammoniacal Liquor.

The strength of ammoniacal liquor is frequently roughly determined by Twaddell's hydrometer, each degree of which is assumed to be equal to two ounces of sulphuric acid per gallon of the liquor, that is, that one gallon of the liquor would exactly neutralise two ounces of absolute sulphuric acid, H_2SO_4. A more accurate method is to saturate the ammoniacal liquor by a standard solution made by diluting sulphuric acid with distilled water until it has a sp. gr. of 1.0643, that is, contains 1 lb. of H_2SO_4 in one gallon at 60° F. It is better, however, not to rely on the sp. gr. of the acid, but to determine the amount of sulphuric acid, H_2SO_4, present in it in the usual way with pure sodium carbonate.†

A 2-oz. burette graduated into 32 equal parts, subdivided into tenths, from which the acid is run, furnishes the means by which the strength in ounces of the ammoniacal liquor is arrived at. One ounce of the liquor is taken, and the acid added until the liquor is saturated, when the strength of the liquor in ounces per gallon is given directly by the burette reading. Slips of litmus-paper, or a solution of methyl-orange, may be used as an indicator. A more convenient method of performing the "saturation" test, and one by which the operator avoids the objectionable gases evolved during the operation, is to first add a known excess of the standard acid to a known volume of the liquor, and boil the mixture in a fume chamber. The excess of acid over and above that required for saturating the ammonia is then estimated by titrating with standard alkali of strength equal to that of the acid.

It is, however, only a portion of the total ammonia which can be estimated by this "saturation" test. There are compounds of ammonia present in gas liquor (the sulphate, chloride, sulphocyanide, &c.) which are not decomposed by the acid; the ammonia in these compounds is called "fixed," and to estimate this it is necessary to heat the liquor with a caustic alkali in order to liberate it.

The acid used may be of the same strength as that already mentioned, namely, 43.75 grains H_2SO_4 in one fluid ounce.‡ A measured quantity of the ammoniacal liquor to be tested is taken, an excess of caustic potash added, and the ammonia distilled over into an excess of the standard sulphuric acid. The sulphuric acid is then titrated with standard alkali, the strength of which is exactly equal to that of the acid.

Fig. 94 shows a form of apparatus which may be used. One ounce of ammoniacal liquor measured by means of a pipette, is put into the flask *a*, and an excess of caustic potash, caustic soda, or milk of lime added. The ammonia is then distilled over through the long bent tube, which is supported at *b*, into the flask *d*, into which through the tube *e* (the bulb of which contains glass beads), 2 ozs. of the standard acid has previously been run. The

* "Journal of Society of Chemical Industry," 1884, iii. p. 157.

† See Notes on the Estimation of Ammonia in Ammoniacal Liquor, by E. L. Pryce, "Trans. Incorp. Inst. Gas Engineers," vol. ii. p. 201.

‡ In large laboratories normal acid is used, as acid of the above strength is not convenient for other purposes. If 25 c.c. of liquor be taken and distilled into 50 c.c. of normal acid, the strength of the liquor expressed in oz. of H_2SO_4 per gallon will be given by multiplying the number of c.c. of acid neutralised by 0.31348

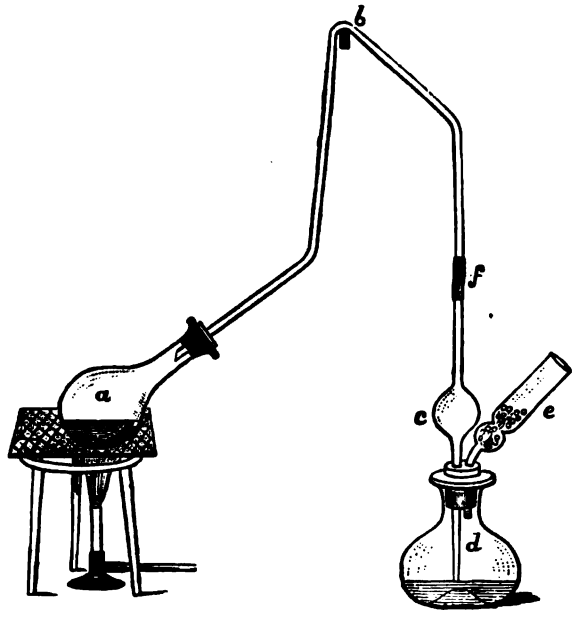
$$0.017 \times 4 \times 4.61 = 0.31348.$$

Digitized by Google

large pipette *c* which is connected to the distilling tube by a piece of india-rubber tubing *f*, prevents any of the liquid in *d* from being drawn over into the distilling flask. In about half an hour all the ammonia will have been driven over with the steam into the acid; the india-rubber tubing *f* may then be disconnected, the pipette *c* and bulb tube *e* removed, after washing them out into *d* with distilled water, and the acid titrated with standard alkali, using litmus or any other suitable indicator.

Ammoniacal liquor is usually sold for removal from the gasworks by the distiller, its price being in many well-managed undertakings regulated by a sliding scale, the variations of which correspond with those of the strength of the liquor and the market value of sulphate of ammonia. The manufacture of the latter, however, from gas liquor is rapidly becoming general in

FIG. 94.



Apparatus for Valuation of Ammoniacal Liquor.

gasworks, more especially at those works where the conveyance of the bulky liquor to buyers at a distance would be costly. The simple character of the operation is also a weighty recommendation for its adoption, an intelligent labourer being able to master the necessary details in about one week's time.

Many of the older methods of making sulphate are now obsolete except in the smallest of works. The primitive method of directly saturating the liquor with sulphuric acid was soon abandoned as clumsy and dangerous and as affording a very impure sulphate.

The ammonia was afterwards obtained in the gaseous state by heating the liquor in a still, from the top of which a pipe conveyed it to a vessel containing sulphuric acid, called the "saturator," in which the sulphate was formed. Old boiler shells were frequently made use of as stills—the liquor being pumped into them, and a fire then lighted underneath. When all the ammonia was evolved, the fire was withdrawn, the waste liquor run away, and the process commenced afresh. This method, besides being

Digitized by Google

discontinuous, is wasteful as regards fuel, and the whole of the "fixed" ammonia is lost, since lime cannot be introduced without endangering the boiler. Lime, however, can be used, if instead of heating by means of a fire, steam be blown through the liquor in the still, but even then the apparatus is anything but economical as regards fuel.

The employment of the Coffey still—originally used in the rectification of spirits of wine—was a great advance on all previous apparatus. In this the liquor flows backwards and forwards in a thin stream over a series of trays, springing alternately from the two opposite sides of the still; it enters at the top and flows out at the bottom, while steam passes upwards over its surface. The liquor from the bottom of the Coffey still runs into a cylindrical boiler where it is treated with lime to liberate the "fixed" ammonia, steam being blown through a perforated pipe running the length of the boiler, thus effecting both agitation and distillation. The steam and ammonia pass from this horizontal still to the Coffey still, the inlet of which is close to the bottom. Towers packed with broken "ganister," coke, or retort carbon are sometimes used instead of Coffey stills. At some works, where large quantities of liquor are dealt with, two cylindrical boilers are employed as stills in which the liquor is treated with lime, while steam at about 20 lbs. pressure is blown through. One still is used while the other is being filled, and the steam and gases given off from the one in use pass upwards through a tower packed with broken ganister, down which the liquor is flowing to the other still.

The ammonia and other gases from the stills are conducted to the saturator, of which there are two forms, one of which is completely covered in, the other only partially so. In the former, which may be described as a large rectangular box, made of stout timbers and lined with strong sheet lead, dilute sulphuric acid is used. The pipe from the still enters through the cover and lies along the bottom of the saturator, the gases being emitted through perforations in the pipe. When the acid is saturated, steam is first blown through the liquid to expel all the sulphuretted hydrogen, the contents of the saturator are then run into a settling tank, and from thence into leaden evaporating pans (heated by steam coils). The sulphate as it crystallises is taken out from time to time and placed upon a drainer.

In the other form of saturator, which is that more generally used, only a portion of the top is covered over, being divided from the open portion by a lead partition descending into the liquid. A more concentrated sulphuric acid is used, and the salt, as it crystallises in the saturator, is removed at the open portion by perforated ladles to the drainer, from which the drainings flow back to the saturator.

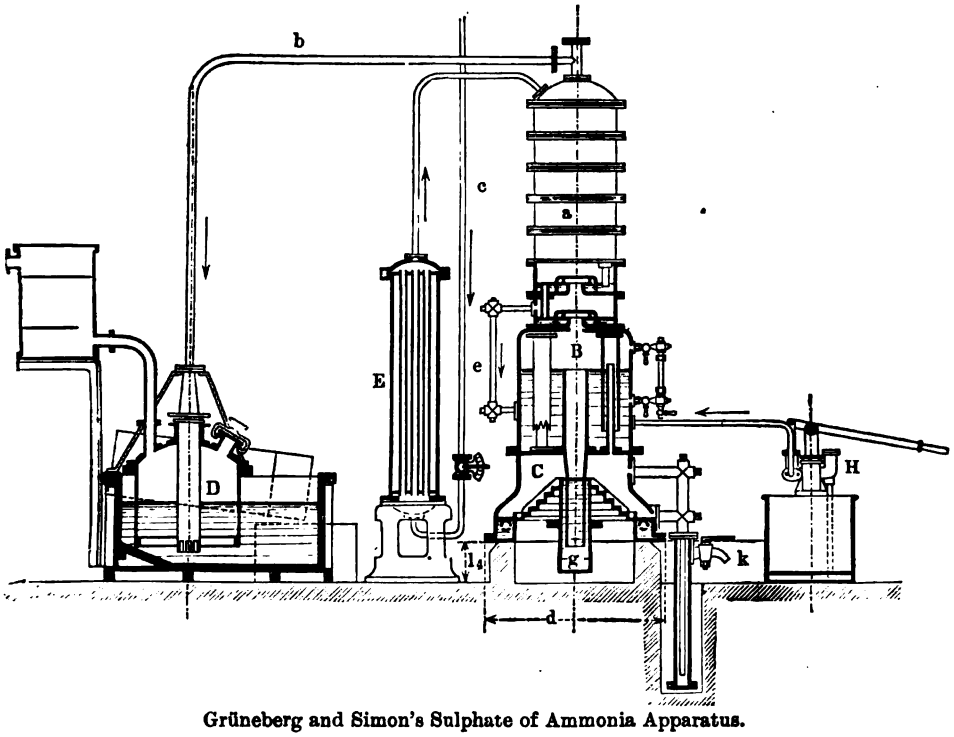
Both forms of saturator are provided with an exit pipe for the waste gases—consisting chiefly of sulphuretted hydrogen and carbonic acid—which are led through "coolers," in which the water vapour is condensed, and are then disposed of in several ways. They may be passed into a furnace, or, if the sulphurous anhydride—produced by the combustion of the sulphuretted hydrogen—is likely to cause a nuisance, through an oxide of iron purifier. At some works the sulphuretted hydrogen is utilised in the production of sulphur by means of the Claus kiln (hereafter described); while at the works at Beckton, Birmingham and elsewhere, it is burned into sulphurous anhydride, which is made use of in the production of sulphuric acid.

The illustrations show some of the modern continuous methods of treating gas liquor, in which not only is the maximum amount of sulphate obtained, but also a considerable economy in fuel is effected, the quantity of steam used being comparatively small.

Digitized by Google

Fig. 95 represents the apparatus used for manufacturing sulphate of ammonia (Dr. Grüneberg and H. Simon)—*a* B C being the still, E the economiser for heating the gas liquor, H the lime pump, and D the saturator. The gas liquor enters the economiser through the pipe *c*, where its temperature is raised considerably before entering the still *a* B C. In the top portion *a* of the still, the "volatile" ammonia is distilled off, the fixed salts being dissociated in the lime vessel B, into which milk of lime is pumped by means of the pump H. The pipe *e* conveys the liquor from *a* to B, from whence it overflows into the "mud-catcher" *g*. From this again, it overflows into the boiler C, provided with a stepped cone for boiling the

FIG 95.



Grüneberg and Simon's Sulphate of Ammonia Apparatus.

liquor in a finely divided state; steam is admitted here, and the last trace of ammonia set free. The waste liquor is drawn from the apparatus at *k*.

The steam passes throughout the still in the opposite direction to the liquor, and together with the ammonia vapour by the pipe *b* into the saturator D. The waste gases collect under the leaden bell, and pass into the economiser E, where they serve (as already stated) to raise the temperature of the crude gas liquor.

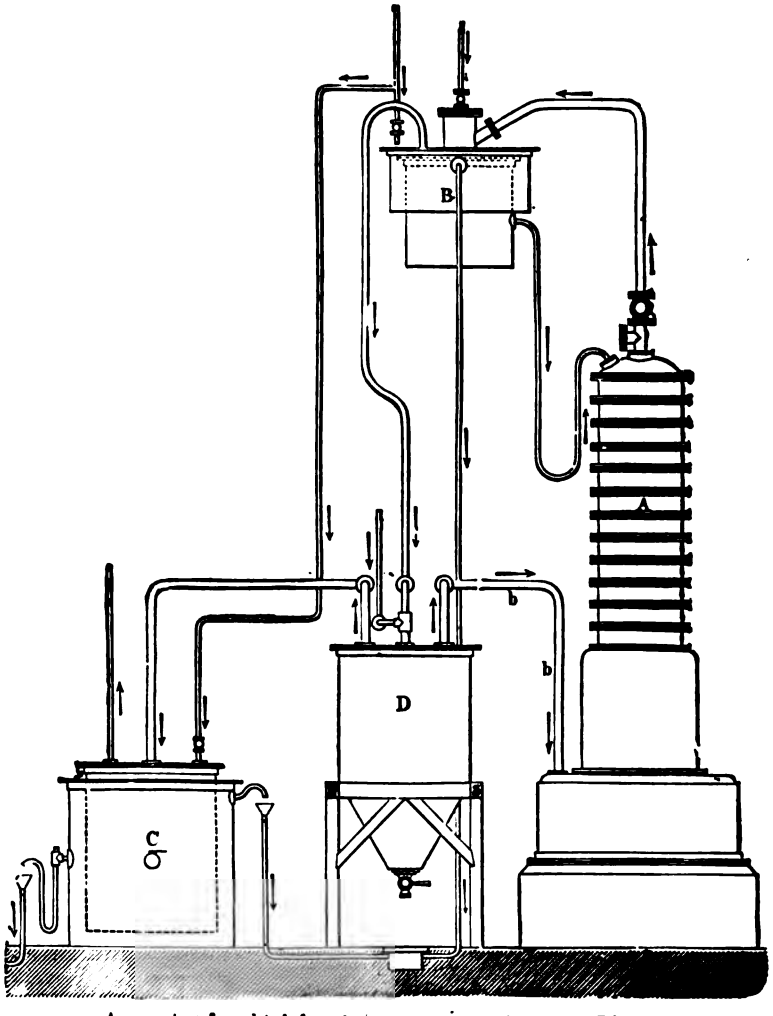
For concentrating the gas liquor, the still A is used with the apparatus shown in Fig. 96. The crude gas liquor enters the vessel B through the pipe *a*; this vessel B serves the double purpose of cooling the vapours coming from the still and of heating the gas liquor, which is then conveyed by the syphon-pipe into the top of the still A. If very strong concentrated ammonia is required, the vapours leaving the vessel B, first pass through lime vessels D (two in number, worked alternately) which are placed side

Digitized by Google

by side, and then into C, in which, by means of cold water in the annular space, the vapours are condensed. If a concentration of not more than 18 per cent. is required the vapours are taken straight to C.

When it is required to manufacture ammonia liquor of considerable purity and strength, the ammonia still A is used in connection with the

FIG. 96.



Apparatus for obtaining Ammonia Liquor from Gas Liquor.

apparatus shown in Figs. 97 and 98. The tank B is similar to the one described in Fig. 91 and serves the same purpose; C, C_1 are lime vessels from which the vapours pass into the lime washers E, E_1, then through a cooler D and charcoal filters F, F_1 F_2, F_3, to be finished ready for market in the absorption boxes G, G_1.

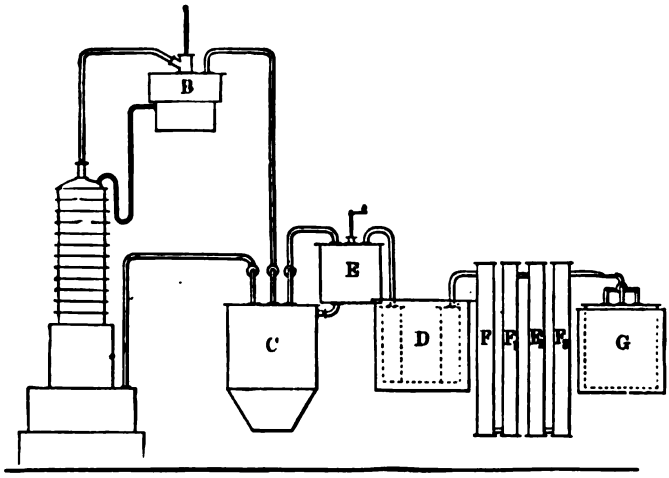
Another modern apparatus (Feldmann's) which likewise possesses the

Digitized by Google

advantages claimed for Grüneberg's is shown in Fig. 99 (p. 104), as arranged for the manufacture of sulphate of ammonia.

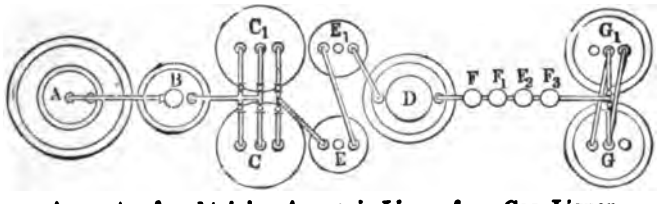
The liquor flows from the feed tank into a supply tank *b*, and from thence to the economiser J, where it is heated by the waste gases coming from the saturator. It then passes into the still A, down which it flows from chamber to chamber, while the steam and hot gases bubble through it. In this way, the volatile ammoniacal compounds are expelled by the time the liquor reaches the bottom. Milk of lime is introduced here by means of

FIG. 97.



Apparatus for obtaining Ammonia Liquor from Gas Liquor.

FIG. 98.



Apparatus for obtaining Ammonia Liquor from Gas Liquor.

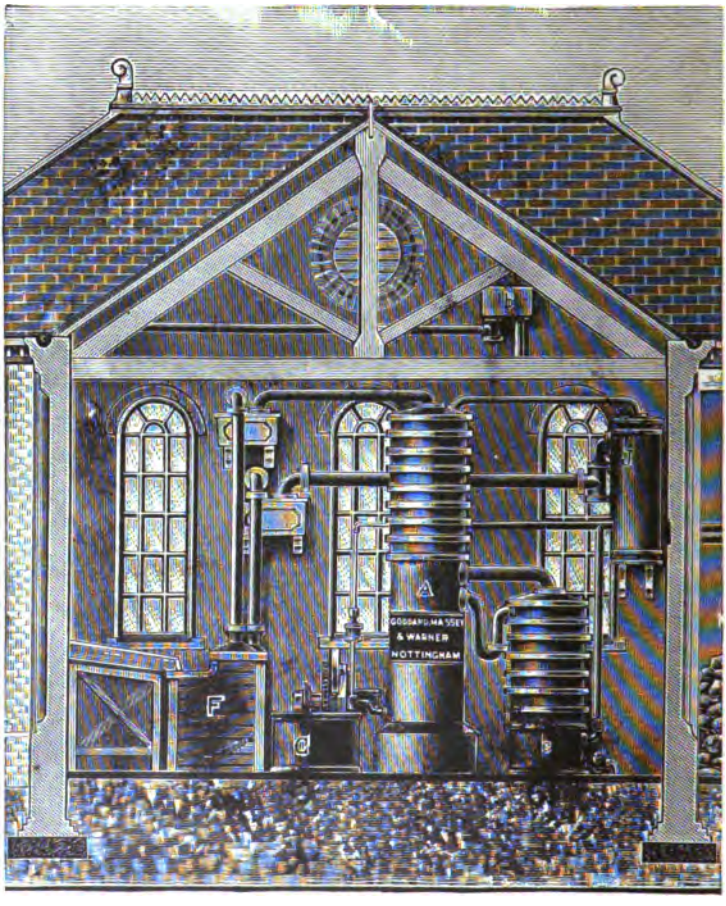
the pump G, and the mixture, after passing through a sieve, flows by the syphon-pipe into C, where the last traces of ammonia are expelled by the steam. The spent liquor flows away, and the steam ascends the column C, passes into A, and after reaching the top of this, is conveyed, accompanied by the ammonia and other gases, to the saturator F.

Fig. 100 (p. 105) shows a complete sulphate of ammonia apparatus with a Wilton's patent automatic discharger, which is worked by steam, depositing the sulphate of ammonia on the drainer. This discharger can be adapted to any existing open saturator or to a group of saturators of any sulphate of ammonia apparatus, and dispenses with the use of scoops or ladles for fishing out the ammonium salt. It is said to cause a constant and thorough mixing of the liquid in the saturator, ensuring uniformity of strength, and does not allow it to become neutral behind the midfeather as long as it

Digitized by Google

remains acid outside. It also increases the durability of the saturator by preventing all wear and tear beyond that caused by the boiling acid, and enables the sulphate to be taken out at 24 per cent. or 24½ per cent. as may be desired, in about ten minutes, as against a much longer time by the laborious process of fishing by manual labour; if desired, the sulphate may be allowed to reach 25 per cent. or even 25½ per cent. of ammonia, NH_3.

FIG. 99.



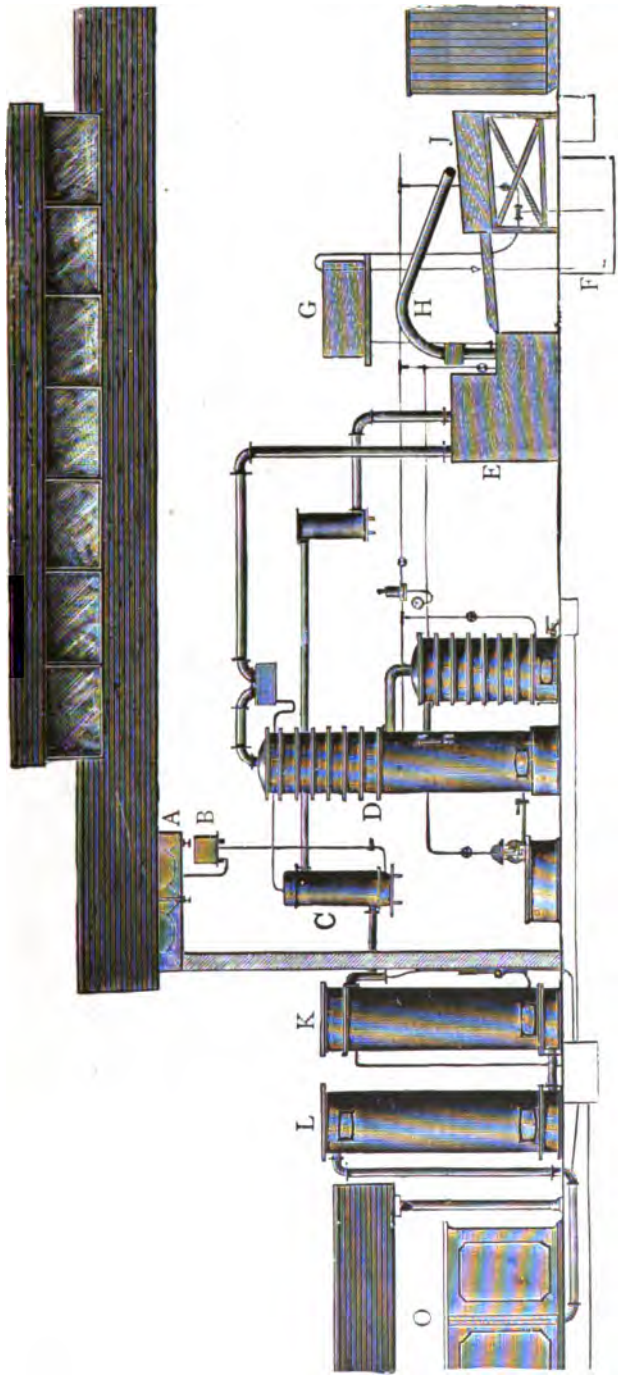
Feldmann's Apparatus for the Manufacture of Sulphate of Ammonia.

The quantity of sulphate of ammonia made per ton of coals carbonised varies from 24 lbs. to 30 lbs. and even more. It depends in the first place on the capability of the coals for producing ammonia; afterwards upon the care bestowed in extracting the ammonia from the gas made, and in the storage of the ammoniacal liquor. It also depends on the efficiency or otherwise of the apparatus used in its production and its purity when made.

About 2600 gallons of 10-oz. liquor are required to produce 1 ton of sulphate of 25 per cent. strength.

Digitized by Google

FIG. 100.



Sulphate of Ammonia Apparatus with Automatic Discharger.

A, B, Liquor tanks; C, Heat economiser; D, Still; E, Saturator; F, Drainage tank; H, Sulphate discharge pipe; I, Drainer; K, L, Condensers; O, Purifier.

Digitized by Google

The following particulars have been supplied by Mr. J. F. Bell, manager of the Stafford Corporation Gas works.

Cost of production per ton of 24½ per cent. NH_3 good grey ammonium sulphate.

	£	s.	d.
Sulphuric acid made from spent oxide	2	7	3
Labour, including bagging, repairs to plant, &c.	0	9	8
Fuel, say	0	5	0
Bags	0	2	6
Lime	0	2	0
Total	£3	6	5

The effluent gases from the saturator contain approximately 24½ per cent. of hydrogen sulphide, and the sulphur is recovered by means of a Claus kiln. This amounts to 140 lbs. per ton of sulphate of ammonia, which means 1½ lb. of sulphur obtained per ton of coal carbonised.

The under-mentioned is a typical analysis of gas liquor, the strength being 5.1° Tw. at 60° Fahr.

ANALYSIS.

Volatile ammonia	1.85	per cent., or lbs. in 10 gallons.		
Fixed "	0.56	"	"	"
Total	2.41			
Hydrogen sulphide	0.82	"	"	"
Carbonic acid	3.17	"	"	"

Mr. Alfred Colson, engineer to the Leicester Corporation Gas Department, in his inaugural address to the Incorporated Institution of Gas Engineers,* gives some valuable information on distillation of tar and the manufacture of sulphate of ammonia, founded on his own experience at Leicester.

The residual works, which are capable of dealing with 80,000 gallons of tar, and of making 100 tons of sulphate per week, cost—

For buildings	£11,927
" sulphate plant	4,631
" tar plant	3,459

The dissected cost for making one ton of sulphate for the year 1893, was given as follows—

	s.	d.
Salaries	2	5.19
Wages	10	9.92
Repairs and maintenance	5	8.82
Fuel†	0	0.96
Sulphuric acid	35	7.04
Lime	1	9.43
Bags	2	3.35
Carriage (liquor)	1	4.46
Do. (sulphate)	4	2.97
Stationery and printing	0	1.22
Gas	0	9.80
Water	0	4.94
Depreciation	6	4.70
Interest	5	4.94
Loss on sulphur recovery	0	5.80
Sundries	0	10.51
Total	£3 18	10.05

* "Trans. Incorp. Inst. Gas Engs." 1894, vol. iv. p. 19.
† Breeze dust used as fuel under forced draught.

Digitized by Google

The profit made on the sulphate per ton of coal carbonised amounted to *2s.* 3·55*d.*

It has been ascertained from Messrs. Bradbury and Hirsch's annual report of the market for sulphate of ammonia (1893) that the variation in price paid per ton for good grey 24 per cent., f.o.b. Hull, for the years 1867–1887 inclusive, was from £11 3*s.* 7½*d.* (in 1886) to £21 (in 1873). And that the average price per ton and number of tons produced in Great Britain and Ireland for the nine years, 1888–1896, have been as follows:

		Price. £	*s.*	*d.*		Production. Tons.
1888	...	11	18	0½	...	122,800
1889	...	12	1	4½	...	133,000
1890	...	11	9	0	...	134,000
1891	...	10	15	5	...	143,650
1892	...	10	1	10½	...	159,850
1893	...	12	11	4½	...	152,500
1894	...	13	3	8½	...	160,000
1895	...	9	15	4½	...	179,500
1896	...	7	18	0½	...	189,000

Cyanogen.

When coal is carbonised at a fairly high temperature, cyanogen is formed in considerable quantities, attended, however, by a reduction in the yield of ammonia.

Mr. Charles Hunt, in his paper entitled "Notes on Residuals," read at the meeting of the Incorporated Institution of Gas Engineers in 1896, states: "The quantity which may be extracted from the gas varies considerably, all experiments tending to show that cyanogen is essentially a high temperature product. Thus the author has found from experiment that gas which is produced under what may be called moderate heat—viz., from 1500° to 1600° F. —yields only about ½ lb. of crystallised sodium cyanide per 10,000 cub. ft. of gas made, corresponding roughly to one ton of coal carbonised; whereas with higher heats, ranging from about 1700° F. upwards, a yield of from 3½ lb. to nearly 6 lb. may be obtained. In connection with these results, however, it can hardly be without significance that the smallest yield of cyanogen is accompanied by a very abundant yield of the other nitrogen product—ammonia; the average of six months' working being represented by upwards of 40 gallons of 10-oz. liquor per ton of coal carbonised. It therefore appears that the conditions which are unfavourable to the production of cyanogen are favourable to that of ammonia, and *vice versâ*. It has been suggested as not improbable, judging from the entire absence of nitrogen in many samples of gas which have been formed at high temperatures, that ammonia in the presence of hydrocarbon gases, is not then broken up into its elements, nitrogen and hydrogen, but that its nitrogen combines with carbon to form cyanogen."

Until lately the only method practised for the extraction of cyanogen from coal gas was by means of oxide of iron, which when spent often contains a considerable quantity of prussian blue. Spent oxide has for many years been treated for this product in Germany, where, owing probably to the presence of a large percentage of cyanogen in the gas, the quantity recovered is occasionally very considerable.

The extraction of this residual from coal gas has formed the subject of many patents, but probably the first practical application of a separate and direct process with this object was made by Mr. Wm. Foulis, the Gas Engineer to the Glasgow Corporation, who took out a patent first in 1892. Mr. Foulis's process is thus described:

Digitized by Google

"Ferrous chloride is first made by treating slightly diluted hydrochloric acid (common) with an excess of scrap iron in large vats, which should be made of slate.

"The solution of ferrous chloride (in which the iron has been carefully estimated in the laboratory) is then drawn off, and measured into vats containing the requisite quantity of sodium carbonate in solution (1 to 20) to form ferrous carbonate. The ferrous carbonate thus precipitated is allowed to settle, and the clear solution of sodium chloride run away to the drain.

"The wet ferrous carbonate is allowed to run into a tank placed below, containing the theoretical quantity of sodium carbonate in solution to form sodium ferrocyanide upon treatment.

"From this tank the mixture of sodium and ferrous carbonate is run into the first bay of a Holmes washer-scrubber, and is kept well stirred by means of the revolving shaft with its attached bundles of bristles, whilst the coal gas, after its passage through the ammonia scrubber, passes through.

"The hydrocyanic acid contained in the gas combines with the mixture to form ferrocyanide of soda, which is run from the last bay of the scrubber as fast as produced; this being ascertained by testing the liquor in the last two bays occasionally for the presence of free alkali.

"The crude ferrocyanide which is run from the washer is evaporated nearly to dryness in large pans, ladled into barrows, and when cool and consequently solid, wheeled to the stores. In this condition it is said to contain about 75 per cent. of sodium ferrocyanide."

In order to determine the amount of hydrocyanic acid in coal gas, a measured quantity of the gas should be passed through a strong alkaline solution, to which a little solution of iron sulphate has been added.

The alkaline ferrocyanide formed is then converted into prussian blue, from the weight of which the amount of hydrocyanic acid in the gas may be calculated. Many precautions are necessary in order to obtain accurate results.

The gas should be passed, direct from the main, through the apparatus, or, if this is impossible, a "composition" metal service pipe should be used; an iron service pipe will frequently remove a large proportion, if not the whole, of the hydrocyanic acid from coal gas containing a little ammonia.

A very convenient apparatus for absorbing the hydrocyanic acid is a set of Mayer's bromine bulbs, such as are used for estimating sulphur in iron. Into these should be put about 50 c.c. of a mixture of 4 parts of a 30 per cent. solution of caustic potash, and 1 part of a 10 per cent. solution of sulphate of iron. The bulbs should be followed by a small Wolff's bottle containing a little of the same solution. If no darkening of the solution in the Wolff's bottle occur it may be taken as satisfactory evidence that the whole of the hydrocyanic acid has been removed by the solution in the Mayer's bulbs.

Following the Wolff's bottle is an experimental meter for measuring the quantity of gas used. About 5 ft. of gas may be either drawn or forced through the apparatus (according to its position before or after the exhauster) at the rate of about 1 to 2 cubic feet per hour. The alkaline iron solution is then washed from the bulbs into a flask, boiled for about 10 minutes, allowed to get quite cold, and filtered—the filter being washed two or three times with cold water.

The filtrate contains ferrocyanide of potassium equivalent in quantity to the hydrocyanic acid in the volume of the gas passed through the apparatus. A slight excess of hydrochloric acid is added to it, and the liberated sulphuretted hydrogen expelled by blowing air through the solution by means of a foot blower. The precipitated sulphur should now be filtered off, and the filtrate made up with distilled water to, say, 500 c.c. One-half of this is

Digitized by Google

taken and poured into about 100 c.c. of a boiling 10 per cent. solution of ferric chloride acidified with hydrochloric acid, boiled for about 5 minutes, and put aside for the precipitated prussian blue to completely settle. If it be desired to use subsequently the remaining 250 c.c. of the ferrocyanide solution, it should be rendered alkaline, otherwise it will quickly decompose, with loss of hydrocyanic acid. The precipitated prussian blue should be thoroughly washed by decantation, boiling water being used, and the washings passed through a small filter paper, upon which the whole of the blue should be finally collected. All the ferric chloride may be rapidly removed from the filter by washing with boiling dilute hydrochloric acid, followed by two or three washings with boiling water.

The prussian blue is now left on the filter in a pure condition, and the estimation can be completed in two or three ways. The simplest is to drop the filter with its contents into a tared red-hot platinum crucible, which should be maintained in this condition until nothing remains in it but ferric oxide.

Then, if 5 cubic feet of gas have been employed and half of the solution taken, $\frac{\text{Weight of } Fe_2O_3 \text{ in grains} \times 10{,}000 \times 156}{7000 \times 2.5 \times 56}$ = lbs. of $Na_4FeCy_6 12H_2O$ to be obtained per ton of coal carbonised.

Another method is to decompose the prussian blue upon the filter paper with a dilute solution of caustic potash, collecting the ferrocyanide of potassium formed in a porcelain dish placed under the funnel. The filter paper must be well washed with distilled water, and the washings allowed to fall into the dish. The ferrocyanide in the dish may then be volumetrically estimated with a solution of potassium permanganate (1 c.c. = 0·5 grain of $Na_4FeCy_6 12H_2O$ is a suitable strength), which has been standardised by means of pure potassium ferrocyanide. A good end reaction may be obtained by adding the ferrocyanide solution to a large excess of dilute sulphuric acid mixed with a known excess of the standard potassium permanganate solution, and determining the excess of permanganate solution with a solution of ferrocyanide of potassium of equal strength. This method gives very good results if care has been taken to remove sulphuretted hydrogen and sulphur from the original solution as directed above. As a control the iron oxide left on the filter paper after decomposing the prussian blue with caustic potash solution, may be dissolved in dilute sulphuric acid and estimated volumetrically by reduction with zinc and estimation with a standard permanganate or bichromate solution.

A simpler and very satisfactory method is to titrate with a standard solution of a zinc salt. The alkaline solution from the bulbs is filtered to remove oxide of iron, received in a white porcelain dish, and made slightly acid with hydrochloric acid. A solution of zinc sulphate titrated against pure potassium ferrocyanide (1 c.c. = 0.2 grain of $Na_4FeCy_6 12H_2O$ is a convenient strength), is added from a burette with vigorous stirring. After each addition a drop from the end of the stirrer is placed on a piece of filter paper near the margin of a drop of dilute ferric chloride previously placed there. While any ferrocyanide remains in solution the drop, spreading on the paper, will, when it comes in contact with the ferric salt, form a blue line, but as soon as the whole of the ferrocyanide is precipitated as zinc ferrocyanide, this indication ceases and the burette is read. Sulphides do not interfere with this reaction.

Digitized by Google

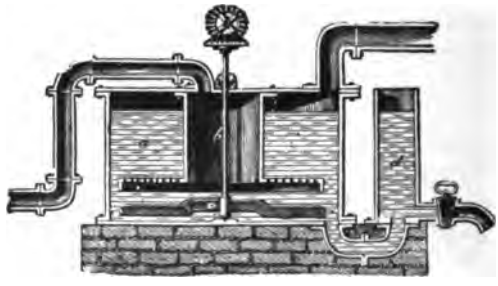
CHAPTER XIII

Purifiers.

The impurities in the gas at the outlet of the scrubbers, and which have to be removed by the purifiers, consist of carbonic acid, sulphuretted hydrogen, carbon bisulphide, and what are known as "other sulphur compounds." In ordinary coal-gas the quantity of carbonic acid varies from about 1 to 3 per cent., or from 815 to 2444 grains per 100 cubic feet of gas; and of sulphuretted hydrogen from about 1 to 2 per cent. or from 630 to 1260 grains per 100 cubic feet of gas. About 20 to 60 grains of sulphur are present in 100 cubic feet of gas in the form of carbon bisulphide and other organic sulphur compounds, the latter contributing from 5 to 14 grains. The quantities of all these impurities vary with the coal used, the temperature of carbonisation, and the efficiency or otherwise of the washers and scrubbers.

It is not perhaps altogether correct to describe carbonic acid as an

Fig. 101



Wet-lime Purifier.

impurity which it is necessary to remove, it being so small in quantity as compared with that which is produced by the combustion of the gas. Its presence, however, prejudicially affects the illuminating power of the gas; and for this and other reasons, as will shortly appear, its removal is desirable.

Very little was at first attempted in the way of purification beyond removal of the tarry matter by condensation, but it soon became necessary to employ means for removing the sulphuretted hydrogen, so that the gas might be burnt without producing an offensive smell. The substance first proposed for this purpose by Henry and Clegg was hydrate of lime, and its efficacy was fully tested on a large scale at a very early period by Winsor. Even to this day, notwithstanding the numerous propositions for substituting other means of purification, lime has been found in many respects the most generally applicable agent for the purpose.

Wet-lime Purifier.—In the first instance, lime was employed stirred up with water, or as milk of lime, in the apparatus shown in Fig. 101. To the lid of the outer vessel, a funnel-shaped pipe, expanding considerably below, is attached, and dips some distance into the milk of lime *a*. The gas entering through this pipe, forces its way through the milk of lime, and escapes by the apertures in the lower part of the funnel. An agitator *b*, worked by rack and pinion through the stuffing-box above, is employed to

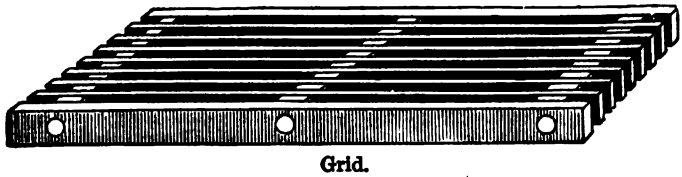
Digitized by Google

keep the milk of lime in constant motion, and to prevent the lime from settling to the bottom of the purifier. The vessel is discharged and filled by means of the additional pipe *d* and the stopcock, whilst a syphon-pipe below prevents any escape of gas.

An improvement on this apparatus was introduced by Malam, consisting of a treble purifier, having three purifying chambers placed one above another. Each chamber was filled to the necessary height with cream of lime, which, as it became foul, was withdrawn from the lowest chamber. This was replenished from the chamber above, fresh lime being introduced into the top chamber.

Another arrangement consisted of placing sets of three purifiers in combination, at different elevations, as previously described *supra*, the cream of lime being caused to flow by gravitation through each in succession, and withdrawn, when spent, at the lowest of the series. The gas was made to take the opposite course, entering, impure, the lowest purifier, passing upwards, and leaving, purified, at the outlet of the highest.

FIG. 102.



Grid.

The pressure exerted on the gas in the retorts by the column of liquid through which it has to pass in the wet-lime purifier was very objectionable, moreover much nuisance was occasioned by the foul material, or "blue billy," as it was called, which could be disposed of only with the greatest difficulty. A great improvement was effected by the employment of lime in a moistened condition, and commonly known as "dry lime," the apparatus for which was first introduced by Phillips, and subsequently made practicable by Malam. This consists of a rectangular or round iron vessel, containing a number of gratings made of wood, or wrought-iron, Fig. 102, upon which the moist slaked lime is spread in layers of from four to six or eight inches in depth. There may be two, three, or four of such layers, and each purifier is furnished with a movable wrought-iron cover in the form of an inverted box, the sides of which dip into a water-lute of sufficient depth to effectually prevent the escape of gas, Fig. 103 (p. 112). Two, three or four of these purifiers are usually worked in combination, the gas being passed through each purifier of a set in succession, according to the condition of the purifying material. Fig. 104 (p. 113) shows a plan of four purifiers forming a set; each is provided with an inlet and outlet pipe, communicating with a cylindrical vessel, C, which enables the gas to be conducted successively through any three of the purifiers. In the illustration, the direction in which the gas passes through the three purifiers is shown by the arrows, the fourth purifier not being in use; from this purifier, the impure lime is removed, and a fresh supply is introduced. The vessel C is constructed either with a hydraulic valve and movable cap, or the movable cap and seal have their surfaces faced where brought together. The latter method of construction is now most usual, and forms what is known as the dry-faced centre valve, Fig. 105 (p. 113). In lieu of this apparatus, either fourway, or single slide valves, Fig. 106 (p. 114), may be used, and they answer well enough in some cases; but when there are as many as four purifiers in a set, the number of such valves that are required to effect the necessary changes is some-

Digitized by Google

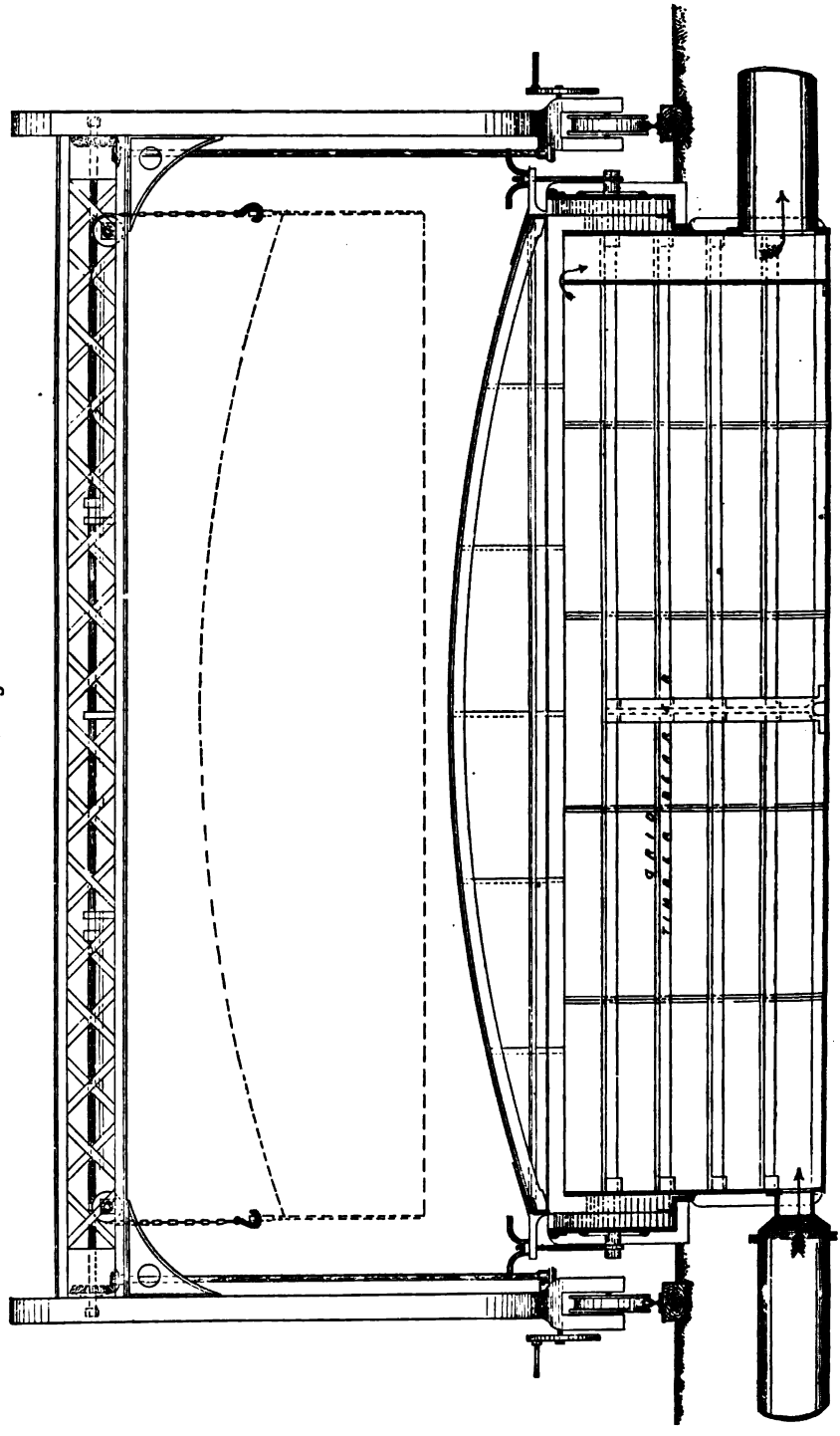
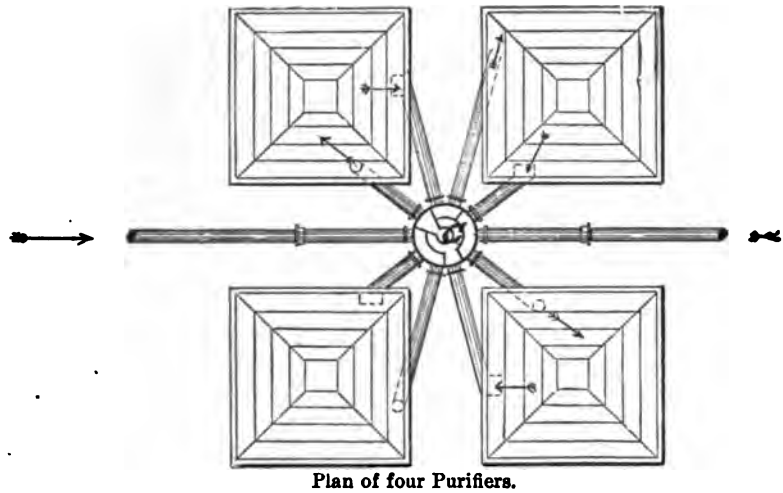


Fig. 103. Purifier.

Digitized by Google

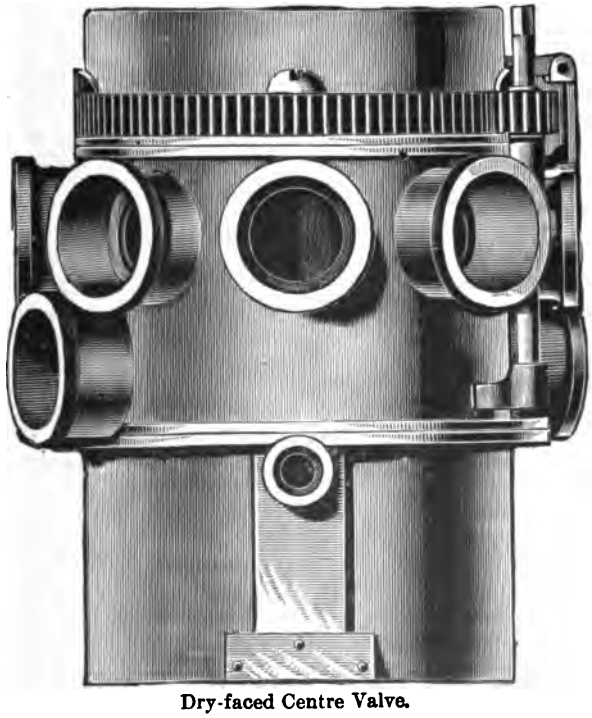
what considerable, and their cost, including connections, is greater than that of a centre valve. Preference is frequently given to valves having a hydraulic

FIG. 104.



Plan of four Purifiers.

FIG. 105.



Dry-faced Centre Valve.

seal, because of the absolute security which these afford against leakage—a point of considerable importance for ensuring the purity of the gas. A very convenient form of hydraulic valve is that of Messrs. S. Cutler & Sons,

Digitized by Google

Figs. 107 and 108, which can be adapted to any combination of purifiers, and by which the purifiers may be changed by simply turning on or off small water cocks. It is not possible for unpurified gas to pass beyond the purifiers when these valves are used, as is inevitable with a centre valve, whether dry or hydraulic, at the moment when the current of gas is changed.

The "Weck Centre Valve," which is largely used on the Continent and

FIG. 106.

Single Slide Valve.

also to some extent in this country, is illustrated by Figs. 109, 110, 111, and 112 (pp. 116 and 117). This valve, unlike the centre valve, Fig. 105. does not allow of foul gas passing unpurified whilst the operation of changing a box is being performed.

The working of the apparatus is simple, all that is necessary being to see that the valves on the inlet to the first, and outlet to the last boxes at work are screwed up to the top, all the rest being kept down. Thus, if the valves on the inlet and outlet of the first box be screwed up to the top, all the rest being kept down, this box only is at work; if the outlet valve from the second box be raised and the valve on the outlet of the first screwed down, the two boxes will be at work, and so on for all four. Again, if necessary, the gas made may be divided into two streams, one half of it going through two boxes, and the other half through the remaining boxes, with very great reduction of pressure, the inlet valves of the first and third boxes and the outlet valves of the second and fourth being raised for the purpose.

Digitized by Google

The valve consists of three tiers of compartments placed one above the other. Fig. 112 shows a horizontal section through the bottom compart-

FIG. 107.

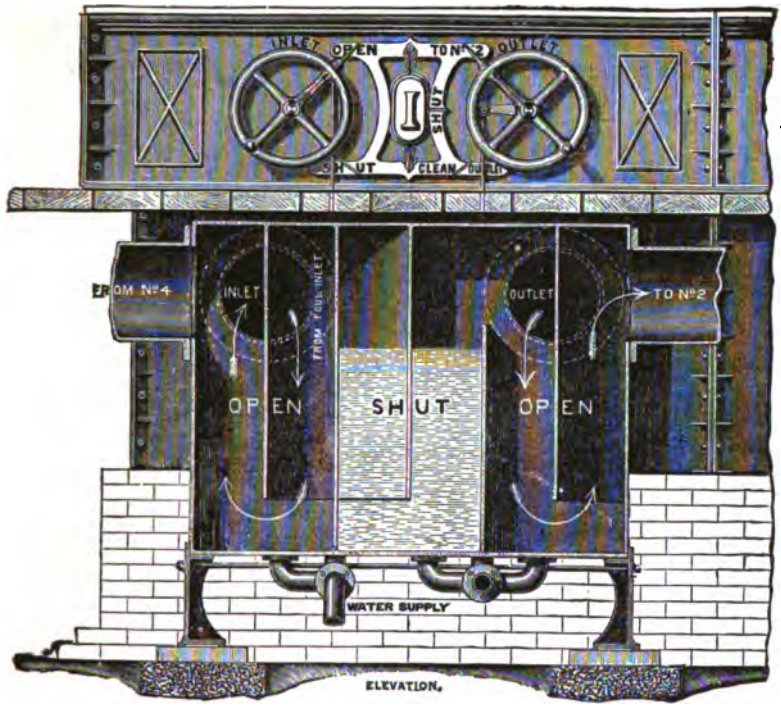
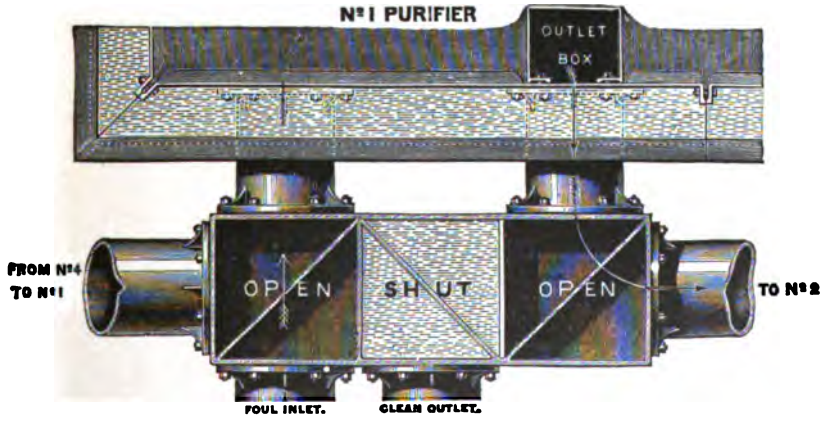


FIG. 108.

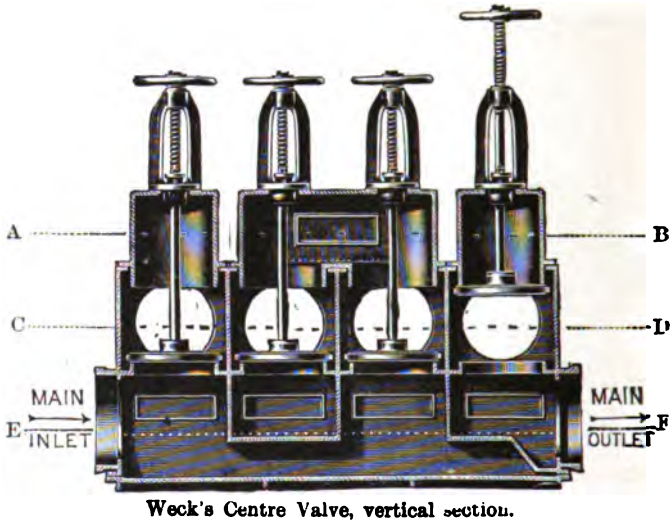


ments, of which there are two, O^1 O^2 O^3 O^4 connected with the outlet main from the purifiers, and I^1 I^2 I^3 I^4, the parts shown freely communicating with each other underneath O^1 O^2 O^3 O^4, and in connection with the inlet main to purifiers.

Digitized by Google

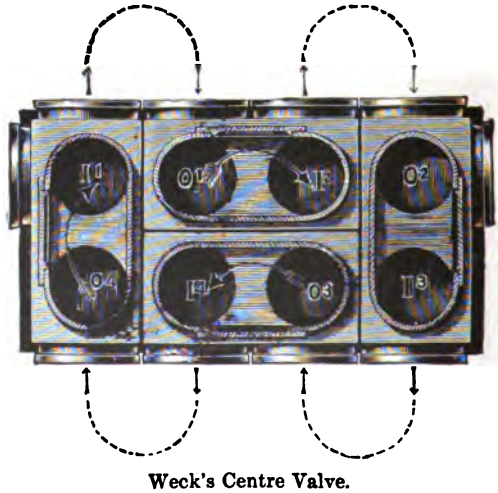
The middle tier, Fig. 111, contains eight separate compartments, O^1 O^2 O^3 O^4, which form the terminals of the outlet mains from the four purifying boxes, and I^1 I^2 I^3 I^4, which form the terminals of the inlet mains

FIG. 109.



Weck's Centre Valve, vertical section.

FIG. 110.



Weck's Centre Valve.
Horizontal section on line A B.

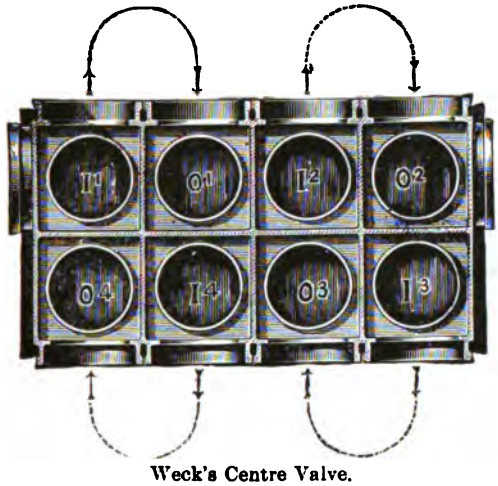
of the boxes. In each of these compartments there is a double-faced valve actuated from above, as shown in Fig. 109. Each compartment, in addition to the side opening to the main, contains an opening at the top communicating with the top compartments and another, at the bottom, opening into the bottom compartments. When the valves are screwed down the lower openings are closed, and the upper openings opened, and *vice versâ* when the valves are screwed up.

Digitized by Google

The top tier, Fig. 110 consists of four compartments $O^1 I^2$, $O^2 I^3$, $O^3 I^4$, $O^4 I^1$, serving to put into communication the outlet of one box with the inlet of the next, when the valves are down.

It will readily be seen that if the valve in the compartment I^1 (Fig. 111) be raised to the top, the lower opening admits the foul gas from the inlet I^1, and as the top opening is closed, the gas must pass through by the side

FIG. 111.



Weck's Centre Valve.
Horizontal section on line C D.

FIG. 112.

Weck's Centre Valve.
Horizontal Section on line E F.

opening and inlet to No. 1 box, through the purifier and back to the compartment O^1, where the valve is down, and the top opening consequently open. It therefore rises to the compartment O^1, I^2, passes down into the compartment I^2, and through No. 2 purifier, and so on to the last compartment O^4. Here the valve is raised, and the gas has therefore to descend into O^4, and away by the outlet main.

The valves are also made for use with three or two purifiers when required.

The water-lute of a purifier varies in depth from 12 inches to 36 inches, according to the size of the purifier and the extreme pressure of gas to which it may at times be subjected; and the cast-iron bottom and sides, together with the wrought-iron cover and fastenings, must be of ample

Digitized by Google

strength to resist such pressure. Cripps gives the following rule for determining the lifting force due to the pressure of the gas:*

Multiply the area of the purifier in square feet by the depth of the water-lute in inches, and by the constant 0.00233 (weight in tons of 1 sq. ft. of water 1 in. deep), and the result will be the lifting force in tons.

Example.—Required, the lifting force to be resisted in the case of a purifier 20 feet square, 5 feet deep, with lutes 2 feet deep by 6 inches wide—

$$20 \times 20 \times 24 \times 0{\cdot}00233 = 22 \text{ tons (about).}$$

The fasteners or holding-down bolts of the cover require to be sufficiently strong to resist this force acting upwards. In the case of the purifier, from this force, which is tending to lift the sides and fracture the bottom plates, there has to be subtracted—

1. A part of the pressure on the bottom in tons.
2. Weight of sides in tons.
3. „ „ cover „
4. „ „ water in lute in tons.
5. „ „ material resting on sides of purifier (say 5 ft. all round).

The pressure on the bottom is obtained by multiplying together the length of the purifier round the sides in feet, the depth of the lute in inches, the constant 0.00233, and the factor L obtained from the following tables:

Depth of lute in inches.	L for ¼-inch plates.	L for ⅜-inch plates.
18	3·37 ...	3·81
21	3·12 ...	3·53
24	2·93 ...	3·30
27	2·76 ...	3·11
30	2·63 ...	2·96
33	2·50 ...	2·81
36	2·38 ...	2·70

Should the sum of these five resistances be less than the total upward lifting force, holding-down bolts, well secured to the foundation, must be placed round the outer edge of the purifier to prevent rupture of the bottom plates.

Occasionally the water lute of the purifier is dispensed with and the covers made flat, either in one piece or in sections, and bolted down to the purifiers by means of flanged joints, the jointing material being either red lead or tallow and hempen gasket.

This plan has been adopted by Mr. H. Green at the Preston Gasworks, and also by Mr. H. E. Jones, of the Commercial Gasworks, Stepney.

There are several ways of arranging purifiers so as to secure economy of labour in filling and emptying them, much of course depending on the general arrangements of the works, and the facilities for bringing in the supply of fresh material and disposing of the spent. One of the simplest of these is to place the purifiers in a row, upon foundations sunk a little below the ground line, with sheds ranged on each side of them, for the storage and preparation of the purifying material. Another plan is to enclose the purifiers within a building having a substantial upper floor, on which the material is prepared for use, and from which the purifiers below can be charged with the least possible amount of labour. Sometimes, also, the purifiers are placed upon girders supported by cast-iron columns at a height above the ground line, sufficient to admit of the purifying material—whether lime or oxide of iron—being prepared underneath them, in which case an opening is provided

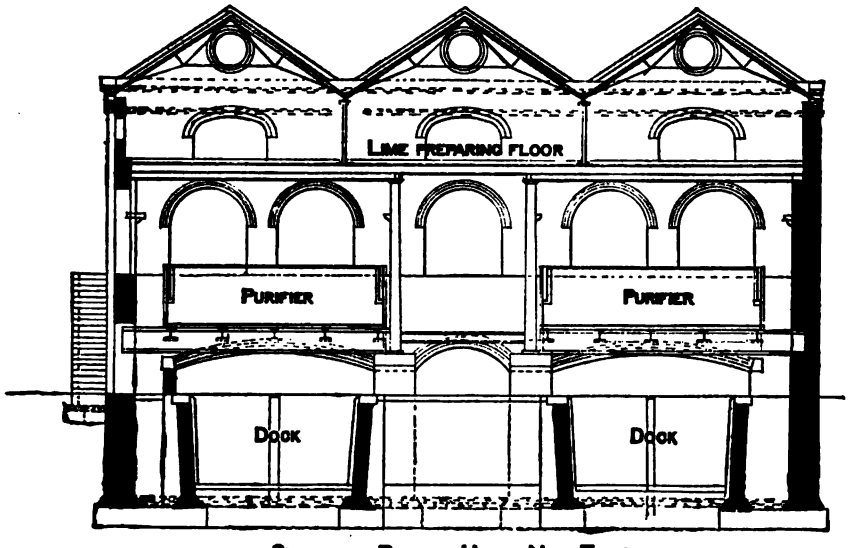
* "The Guide-framing of Gasholders, &c.," by F. S. Cripps, Assoc. M.Inst.C.E., p. 100, *et seq.*

Digitized by Google

in the bottom of each, secured by a gas-tight cover through which they are discharged. Elevators are employed for raising the fresh material when the purifiers require to be recharged.

Perhaps the most economical plan of all is that which was adopted by Mr. John Methven when engineer of the Nine Elms Gasworks. Fig. 113 shows a sectional elevation of his purifying-house, in which there is not only a floor below the purifiers, as in the plan already mentioned, but also a floor above, up to which the fresh lime as it arrives is hoisted by means of a steam crane, and on which it is slaked ready for use in the purifiers. By this arrangement the purifiers are both charged and discharged with an absolute minimum of labour. Exceptional facilities are also afforded for the removal of the spent lime by the water-dock, which extends within the building, and communi-

FIG. 113.



SECTION OF PURIFIER HOUSE, NINE ELMS.

cates, at high water, with the river Thames; barges can thus be placed immediately below the purifiers, to receive their freight.

The wrought-iron cover has necessarily to be lifted, and in most cases moved away, from the purifier each time a supply of fresh material is required. In Fig. 103 is shown a travelling "Goliath" having an ordinary crab winch at each end for effecting this; but when the cover is of very large dimensions and therefore of considerable weight, it is often desirable to employ other means. For a purifier say 40 feet by 30 feet—which is not at all an uncommon size, some being even larger—the cover would probably weigh not less than 12 tons, and for such a heavy lift hydraulic power is very suitable. A very large cover may be safely lifted at four points, namely, two on each side, by multiple chain gearing actuated by a ram placed horizontally upon an overhead traveller, and this arrangement possesses the advantage of enabling the cover to be moved clear away from its purifier; moreover, one traveller can be used for several purifiers if they are placed in a row. Or the cover may be lifted by means of a ram acting vertically through the centre of the purifier. This plan, however, does not admit of the cover being moved away from its purifier, and the top of it must be made much stronger than is usual when the lift is taken from the sides, so as to withstand the great

Digitized by Google

strain due to the whole weight of the cover having to be supported from the centre.

A very simple and efficient application of hydraulic power to this purpose has been adopted by Mr. W. Foulis, Gas Engineer to the Glasgow Corporation. A ram working vertically through the water-lute is applied underneath each of the four corners formed by the cover-sides, all of them being connected to one pressure-pipe, so that the pressure upon being exerted bears equally upon all. When the cover is lifted to the full height required, it is mounted upon grooved wheels, fitting the edge of the water-lute, along which it is moved over to the adjoining purifier.

In connection with any of these plans, the hydraulic power may be applied either by a movable hand-pump, or by coupling up to a pressure-pipe leading from an accumulator worked at a distance, if this be available.

Each purifier in a set should have an area of at least $\frac{4}{10}$ths of a superficial foot for each 1000 cubic feet required to be purified every 24 hours; with lime there should be at least three layers, about 6 inches to 9 inches deep. Experience shows that a large area is favourable not only to economy of purifying material, but also to effective purification, and the above proportion may with advantage be exceeded. Mr. C. Hunt proposed* that in determining the area of purifiers to be used with lime, regard should be given to the amount of carbonic acid to be removed from the gas, and suggested an area of $\frac{1}{10}$th of a superficial foot per 1000 cubic feet per 24 hours for every $\frac{1}{2}$ per cent. of the maximum quantity of carbonic acid in the gas.

CHAPTER XIV.

Purification.

PURIFICATION may be either partial or complete, according to Parliamentary restrictions or the wishes of the supplying company or local authority. Partial purification may consist of either (1) the removal of sulphuretted hydrogen only—usually effected by means of oxide of iron—the absence of which from the gas sold is compulsory in all parts of the United Kingdom; or (2) the removal of sulphuretted hydrogen and carbonic acid, generally effected by first removing sulphuretted hydrogen with oxide of iron, followed by the removal of carbonic acid by means of moist slaked lime. By complete purification is meant the removal of sulphuretted hydrogen, carbonic acid, and carbon bisulphide, other sulphur compounds (representing from 5 to 14 grains of sulphur per 100 cubic feet of gas), not amenable at present to any process of purification, being left in the gas. To effect the removal of carbon bisulphide it is necessary to bring the gas, after removal of the carbonic acid, into intimate contact with an alkaline sulphide.

Partial Purification.—(1) *Removal of Sulphuretted Hydrogen only.*—This is very easily and cheaply removed by means of moistened oxide of iron.

Laming patented the use of oxide of iron, mixed with chloride of calcium or sulphate of lime, in the same vessel, for the removal of the ammonia and sulphuretted hydrogen in a single operation. Croll proposed roasting the spent oxide of manganese (to which material he appears at first to have given the preference) in an oven with constant agitation, by which means the sulphur was converted into sulphurous acid, and the oxide was said to be obtained in a condition to be again used in the purifier. This process of revivifying by artificial heat, which had been previously tried with the waste gas-lime, did not pay.

* Hunt on the Construction of Gasworks, "Proc. Inst. C.E.," vol. cxvii. 225.

Digitized by Google

Laming, however, obtained a patent in France for renewing the hydrated oxide of iron by exposure to the action of the atmosphere, but this process was not applied in England until its rediscovery by Evans. Hills also laid claim to the use of the hydrated and precipitated oxides of iron, and various earthy and alkaline salts, when mixed with sawdust or breeze in the dry-purifier.

The chemical action which occurs in the purifier when the hydrated oxide of iron is employed, consists in the formation of water, the conversion of a part of the oxide into ferrous sulphide, and the deposition of sulphur. The chemical changes which take place are in all probability represented by the following equations, the first of which largely predominates:

$$Fe_2O_3H_2O + 3H_2S = Fe_2S_3 + 4H_2O, \text{ and}$$
$$Fe_2O_3H_2O + 3H_2S = 2FeS + S + 4H_2O.$$

Exposed subsequently to the air, the ferrous sulphide is decomposed by the oxygen with regeneration of oxide of iron and deposition of sulphur. The heat evolved by this process of spontaneous oxidation is often sufficient to ignite the sulphur, when the whole mass becomes very hot, and volumes of sulphurous acid are evolved, whilst the great heat generated seriously injures the absorbent properties of the oxide. With ordinary care, however, excessive heating can be avoided, and the mixture after exposure is often capable of purifying a larger volume of gas than when used for the first time—a circumstance which is probably due to its greater porosity.

In this way the oxide can be used again and again until it has become charged with fully its own weight of sulphur, when it is a valuable commodity, often realising, for sulphuric acid manufacture, more than the original cost of the oxide, whilst on the Continent, and in some places in England, it is also valuable for the large amount of prussian blue which it contains. The following were the percentages of sulphur taken up in each working by an oxide of typical quality:—

1st working . .	6 per cent.	6th working . .	29 per cent.
2nd „ . .	12 „	7th „ . .	35 „
3rd „ . .	14 „	8th „ . .	45 „
4th „ . .	19 „	9th „ . .	51 „
5th „ . .	24 „	10th „ . .	56 „

In many places a little air is admitted with the gas, which causes a partial revivification of the oxide *in situ*, and a saving in labour is thus effected.

The author of the "Chemistry of Gas-lighting" suggested a mixture of clay or loam with the oxide of iron, in place of the sawdust which is frequently employed to render the mass porous. A mixture of this kind, where organic matter is not present, would also admit of the sulphur and cyanogen compounds being more easily removed from the saturated material.

One of the principal sources whence purifying oxide is at present obtained is the bogs of the north of Ireland, the bog ore being merely dug out, laid a few days to weather and dry, and shipped for use. A very good artificial oxide is prepared by a process patented by McDougall, in which copperas is decomposed by lime, and mixed with a due proportion of sawdust and burnt residue from spent oxide. Ironstone refuse finely ground is sometimes used.

(2) *Removal of Sulphuretted Hydrogen and Carbonic Acid.*—This is most systematically effected by employing separate purifiers filled with lime, through which the gas passes after the removal of sulphuretted hydrogen by means of oxide of iron. The resultant carbonate of lime is then an innocuous substance, and in country districts is frequently sold to the

Digitized by Google

farmers at a few shillings per ton. It may also be converted into lime and used repeatedly by treating it as hereafter described.

The removal of carbonic acid considerably improves the illuminating power of coal gas. According to trustworthy experiments, one per cent. of carbonic acid adversely affects the illuminating power to the extent of about 3 per cent.,* so that assuming the presence of 2 per cent., which is about an average quantity, the gas would be depreciated 6 per cent., or, with 16 candle gas, 0·96 of a candle. The removal of this amount of carbonic acid, at a cost for labour and lime of, say, ½*d.* per 1000 cubic feet, bears favourable comparison (even after taking into consideration the value of the metered carbonic acid, &c.), with the cost of an equal addition to the illuminating power by means of cannel, this being about 2*d.* per candle per 1000 cubic feet; the gas, moreover, burns with a brighter flame.

Complete Purification.—*Removal of Sulphuretted Hydrogen, Carbonic Acid, and Carbon Bisulphide.*—Until about the year 1850, when the use of oxide of iron was introduced, there was no recognised test for the presence of sulphur compounds in coal-gas other than sulphuretted hydrogen, and it was not until the year 1860, when the Metropolis Gas Act was passed, that their removal, or partial removal, was rendered obligatory on the part of the Gas Companies, the maximum amount of sulphur in any form being restricted to 20 grains per 100 cubic feet of gas. In the year 1868, further legislation resulted in the appointment of three Gas Referees, whose duties were to fix from time to time the mode of determining the illuminating power of the gas, and also to decide as to the amount of sulphur to be allowed in it, having regard to the possibility of their instructions being observed without nuisance in the neighbourhood of the works. This condition was rendered necessary by the fact that the only then known method of reducing the sulphur compounds was by the use of lime, which had come to be regarded as highly objectionable. In 1872, Mr. Patterson, who was then acting as one of the Referees, patented a process for using lime, in which, by first removing the carbonic acid, sulphide of calcium is produced in a separate series of purifiers and can be employed for the elimination of the carbon bisulphide; any remaining sulphuretted hydrogen being removed in a third series of purifiers charged either with lime or with oxide of iron. Mr. Patterson thus describes his process:

"Suppose that four lime purifiers are employed, the gas may be passed through the first two vessels until carbonic acid appears in the gas issuing from No. 2. As soon as this occurs, No. 1 (the contents of which are now carbonated) is recharged with fresh lime, and used in the second place in the series, No. 2 being used as the first of the series. By the time carbonic acid again appears in the gas issuing from the second vessel of the series (which was previously No. 1), the lime in the first vessel (previously No. 2) will be fully carbonated, whereupon it is to be recharged and used as the second vessel of the series, and so on. In this way the carbonic acid is wholly removed from the gas by these two first vessels of the series, while the lime which they contain is converted into carbonate, in which state it can be removed from the purifiers without occasioning much nuisance.

"In consequence of this mode of employing the two first purifiers, the lime in the third purifier is converted into sulphide of calcium by means of the sulphuretted hydrogen expelled from Nos. 1 and 2 by the carbonic acid. And as sulphide of calcium absorbs bisulphide of carbon, the gas in passing through No. 3 will be purified from sulphur in both forms—*i.e.*, both from sulphuretted hydrogen and from bisulphide of carbon. The last

* *Vide* C. Hunt on Purification," Trans. Incorpd. Inst. Gas Engineers," vol. ii, 103.

Digitized by Google

vessel of the series, No. 4, will be employed to arrest any sulphur passing forward in the gas from No. 3. When No. 3 (the sulphide of calcium purifier) is recharged with fresh lime, it may be used last in the series—No. 4, the lime in which is by this time partially sulphuretted, being placed before it as No. 3.

"When found advisable (as it may be in some cases), the sulphide of calcium purifier, instead of being at once recharged with fresh lime, may be transposed into the first or decarbonating series of vessels, where its contents will be gradually carbonated, while sulphur in usual quantity will be sent forward into the subsequent vessels.

"In order to lessen the quantity of lime used, oxide of iron may be employed after the sulphide of calcium purifier, No. 3—the three lime purifiers being worked as before—viz., the two first vessels as decarbonators, and the third to absorb a portion of the sulphuretted hydrogen expelled from the previous vessels, whereby the contents of this vessel (No. 3) are converted into sulphide of calcium, and maintained in that condition as long as may be required, for the absorption of bisulphide of carbon. The remainder of the sulphuretted hydrogen, passing forward from No. 3, will be arrested in the subsequent oxide of iron purifiers."

Although after costly litigation Mr. Patterson was unsuccessful in sustaining his patent, he unquestionably described a process by which the sulphur can be reduced within the limits prescribed by the Referees; and it continues to be, with modifications, the one very generally employed for the purpose.

Mr. Frank Livesey, in a paper read before the Gas Institute in 1883, described three methods of purification from sulphur compounds, all of which are dependent in their action on the previous removal of the carbonic acid. In the first of these methods ten purifiers are needed—namely, two containing oxide for sulphuretted hydrogen, two containing lime for carbonic acid, four charged with lime for the sulphur compounds, and two with oxide as catch purifiers. An average performance of these vessels was stated to be as follows:—

The first sulphide box removes . .	2.1	grains per 100 cubic feet.	
The second " " . .	1.2	"	"
The third " " . .	6.7	"	"
The fourth " " . .	5.4	"	"
Total	15.4	"	"
The carbonic acid and first oxide purifiers remove	6.0	"	"
Making a grand total of . .	21.4	"	"

which would reduce the sulphur in London gas below the limits prescribed by the Metropolitan Gas Referees, *i.e.*, 17 grains per 100 cubic feet of gas in the summer, and 20 grains in the winter.

When the first box in the sulphide series is doing but little work, the lime is taken out of it, placed in a heap, allowed to heat, and then returned, the portion carbonated being rejected, and fresh lime substituted. It is then worked as the last in the series, and is very active, removing from 5 to 8 grains of the sulphur compounds, a large quantity of sulphuretted hydrogen being driven forward into the catch purifiers, which require careful watching.

This plan is stated to be the most economical, the quantity of lime used being small, although the labour is rather heavy, and the number of purifiers required is large.

The second method depends on the previous elimination of the carbonic

Digitized by Google

acid and a large quantity of the sulphuretted hydrogen, by Hills' process of washing the gas with causticised ammoniacal liquor, to which reference will shortly be made. The gas thus partially purified is made to pass through three lime boxes worked in rotation, which reduce the sulphur compounds to the limit required, and at the same time remove the bulk of the sulphuretted hydrogen. The usual oxide purifiers (three in number) finish the process. The rules adopted for changing the lime purifiers are, that when the first purifier shows more than 33 grains of sulphur, or when the carbonic acid is above 0.22 per cent., a change is required; also that carbonic acid must never show through the second vessel. The quantity of lime used in this process is stated to be small, which is doubtless owing to the previous removal of the carbonic acid. One yard of unslaked lime (21 bushels) purifies the gas made from 35 to 40 tons of coal.

By the third method the gas, after passing through a washer and two scrubbers, first enters a set of four purifiers, three of which are at work, one of them being oxide (which is always first in the series), and two lime. Each purifier, when changed is always charged with a different material to that taken out. A lime becomes an oxide, and is placed first in the series; an oxide becomes a lime, and is placed last. The purifiers are worked in rotation, but the valves are so arranged that any one in the series can be bye-passed at any time. Whenever carbonic acid shows halfway through the second purifier a change should be made. The first oxide purifier removes about 2 grains of the sulphur compounds; the first lime purifier about the same; the second lime from 4 to 6 grains. After leaving these purifiers the gas passes into sometimes one, and sometimes two calcium sulphide boxes. which remove another 3 to 6 grains, and continue to do this for five or six months. These figures relate to a period when the greatest quantity of gas is passing through the purifiers. When the quantity required is less, a better result is obtained.

The cost of the different methods compares as follows:—

		d.					d.	
1st method,		5.23	per ton,	or without	removing	the lime,	4.84	per ton.
2nd	"	6.23*	"	"	"	"	5.52	"
3rd	"	7.10	"	"	"	"	6.19	"

It will be seen that the largest area of purifiers gives the best results, as indicated by the cost of the first method. There can be little doubt that this is due in a great measure to the use of oxide of iron for removing the principal portion of the sulphuretted hydrogen, the sulphur of which is thus converted into a saleable product, and assists to reduce the cost of purification.

Lime alone, when properly used in sufficient quantities, completely removes the carbonic acid and sulphuretted hydrogen, which become converted into carbonate and a sulphide of calcium, the latter being a very efficient agent for the removal of carbon bisulphide.

Previous to the introduction of scrubbers, the mechanical retention of the ammonia was one of the chief causes of the intolerable stench evolved by gas lime when exposed to the air. Sulphide of calcium evolves sulphuretted hydrogen slowly when decomposed by the carbonic acid of the atmosphere, but if ammonia be not present, part is converted into thiosulphate (hyposulphite), which has no smell. In the former case, however, carbonic acid is rapidly absorbed by the ammonia, and decomposition then ensues between the sulphide of calcium and carbonate of ammonium, producing carbonate of calcium and sulphide of ammonium, which escapes with its characteristic odour. So great was the nuisance produced by the effluvia from

* This includes 1 58*d.* per ton for the previous part purification of the gas by Hill's process.

Digitized by Google

gas lime, that numerous plans were at different times suggested for its prevention. At first it was thrown under the ashpit of the furnaces, when the vapours escaped into the fire, and were destroyed; but this plan is quite impracticable in large works. It was then proposed to drive off the sulphur by distillation in a close retort, but this was not found economical. Palmer's plan, carried out by Evans, consisted in sending air through the refuse lime without removing it from the purifier, the latter being connected by a pipe with a chimney draught. The sulphide thus became oxidised, and was then inodorous, the ammonia being driven off, whilst the hydrate and carbonate of calcium remained unaltered. A considerable portion of thiosulphate must thus be produced in the refuse.

This plan of ventilating gas-lime rendered the lime itself inodorous; but the vapours which passed away from it in the process of ventilation, even when passed through a furnace, gave rise to nuisance in the neighbourhood. Such was the case at the works of the City of London Gas Company; and in order to prevent the nuisance complained of, Mr. Mann, their engineer, carried the current of ventilating air, after passing from the lime-purifiers, through another purifier containing oxide of iron, by which the noxious gases were absorbed; and the current of air being continued, the oxide of iron, which at first became saturated with sulphuretted hydrogen, was again oxidised, and thus could be used repeatedly for the same purpose.

This plan has been adopted by Mr. W. Cross at the Leamington Gasworks. The treatment requires to be continued for about 70 hours, at the end of which time the foul lime is rendered quite inodorous. The operation must be carefully watched, it being attended with considerable development of heat, which, unless controlled, is likely to cause damage to the purifiers.

The use of lime alone possesses great advantages in point of simplicity and regularity of action, and the low value to which spent oxide has fallen has of late years tended to again turn the practice of gas engineers in this direction. Moreover, the plan of admitting a moderate percentage of air into the gas is being followed with some advantage; a small percentage of air admitted at the condensers, or other convenient part of the apparatus, has long been recognised as of great assistance in prolonging the activity of oxide of iron, and so avoiding the necessity of frequently changing the purifiers. This process was first introduced by Hills; but the fear of diminishing the illuminating power of the gas by the addition of nitrogen prevented it from being followed to any great extent.

At Brentford, it is stated that the addition of about 2 per cent. of air enables complete purification from carbonic acid and sulphuretted hydrogen to be effected, including a sufficient reduction of the sulphur compounds, using only the same quantity of lime that was formerly required to remove the carbonic acid only, whilst Mr. T. May, Engineer of the Richmond Gasworks, in his presidential address to the Southern District Association of Gas Engineers and Managers in 1890, stated that as much as 3 to 3½ per cent. of air, could be used when the usual sulphur limit was in force. Neither he nor Mr. Leicester Greville was able to detect any but the slightest variation in the illuminating power of the gas, even when the proportion of air admitted varied from 1 to 4 per cent. Here, also, it was found that the quantity of lime ordinarily used for carbonic acid purification only, now sufficed for the removal of both sulphuretted hydrogen and carbonic acid. The spent lime produced was inoffensive; whilst the increased quantity of gas, due to the metered nitrogen, paid for the whole cost of material and labour under this process.

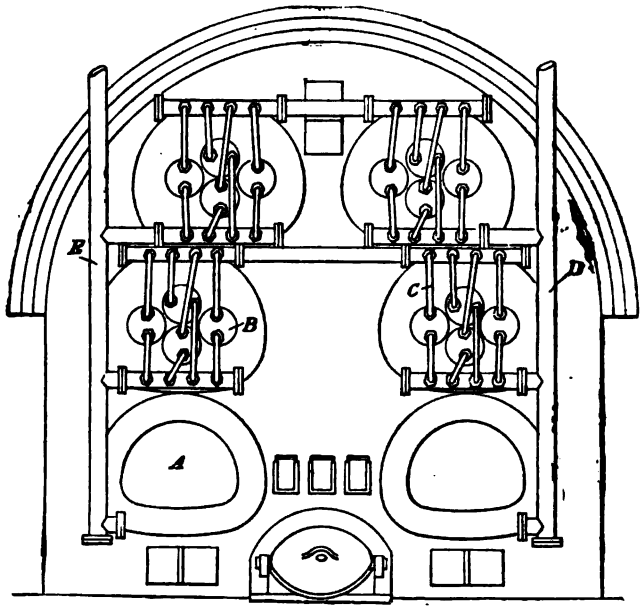
The author, who has had considerable experience* with this method of

* C. Hunt, Purification, "Trans. Incorp. Inst. Gas Engs.," vol. i. 105; also Construction of Gas Works, "Proc. Inst. Civil Engs.," vol. cxvii. 223.

Digitized by Google

purification, but under rather different conditions, owing to the very large amount of impurities in the gas dealt with, is of opinion: (1) that oxygen (air) far from assisting in the removal of sulphur compounds, as has been urged, is actually prejudicial to it, at all events when present in appreciable quantity; (2) that it is mainly of use for the indirect oxidation of the sulphuretted hydrogen, by which economy of lime is effected, and an inoffensive spent material obtained, consisting for the most part of carbonate of lime, with a large proportion of free sulphur; and (3) that the quantity of oxygen, whether employed pure and simple or admixed with nitrogen as air, which may safely be used, while at the same time keeping the "sulphur compounds" within the legal limitations, varies with the quantity of carbonic acid present in the crude gas; *i.e.*, the less the carbonic acid,

FIG. 114.



Oxygen Furnace.

the more the oxygen which can be employed. He has found that when from any accidental cause the quantity of oxygen in the crude gas has been largely increased, almost invariably a corresponding rise in the quantity of "sulphur compounds" in the purified gas takes place, so that sometimes they may be largely in excess of the quantity present in the unpurified gas. Such rise, however, does not take place immediately, owing, in all probability, to the purifiers serving as a kind of reserve or store, and thus there is time for any defective arrangements to be put right.

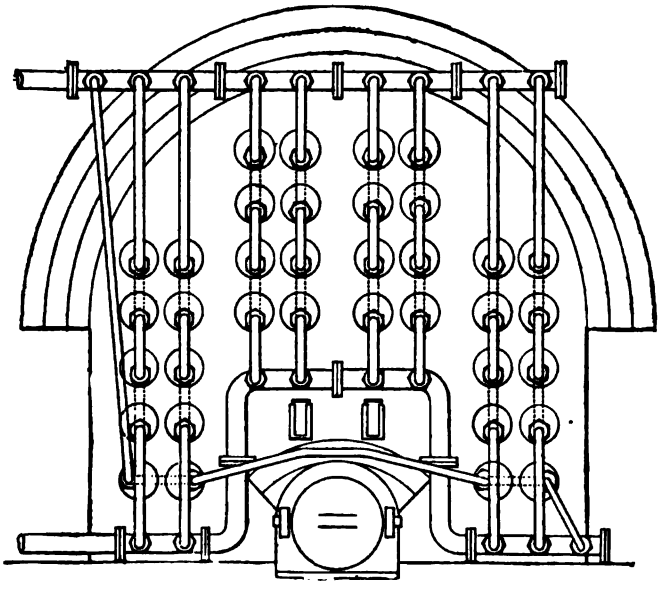
In 1888 and 1889, Mr. W. A. Valon* brought under the notice of the Gas Institute a proposal which attracted the greatest attention. This was no less than the substitution of oxygen pure and simple in place of air, and although at the present time, on the ground of economy, the proposal is not seriously considered, yet the amount of ingenuity which it caused to be expended upon the methods of obtaining a cheap supply of oxygen, entitles it to respectful consideration. The oxygen was made by

* "Trans. of the Gas Institute," 1888, p. 71, and 1889, p. 41.

Digitized by Google

Brins' process, in which air is forced by means of pumps, through purifiers which free it from carbonic acid and moisture, into steel tubes maintained at a temperature of about 1400° Fahr. and placed in furnaces as shown in Figs. 114 and 115. These tubes contain barium oxide, which absorbs the oxygen from the air, barium peroxide being produced, whilst the nitrogen is allowed to escape by means of a relief valve after passing through the tubes. After a given time the pump is reversed automatically, and upon a vacuum of about 25 inches being obtained, the barium peroxide is decomposed into barium oxide again, and oxygen, which is pumped into a gasholder ready for use as required, the process being thus continuous. In addition to the absence of deterioration of coal-gas by nitrogen when air is used in purification as above described—for although other causes may combine to prevent

FIG. 115.



Oxygen Furnace.

this being observed, there is no doubt but that it occurs—it was supposed that the use of oxygen pure and simple had some occult influence in the purifiers which the oxygen of air did not possess. Also it was maintained that sufficient oxygen could be mixed with the gas to completely oxidise all sulphuretted hydrogen, and allow of a little oxygen passing through the purifiers, which was supposed to largely increase the illuminating power of gas. And this at the same time that the "sulphur compounds" were kept below the Referees' limits. None of these statements, however, has met with acceptation.

Considerable light has been thrown on the chemical changes which occur in lime purification by the researches of Divers and Shimidzu* and of Veley,† from which it would appear that the sulphide instrumental in the removal of carbon bisulphide is the hydroxy-hydrosulphide of calcium, $Ca\begin{matrix}HO\\HS\end{matrix}$, formed when sulphuretted hydrogen is passed through *moist* slaked lime.

* "Journ. Chem. Soc." 1884, xlv. 270. † 'Journ. Soc. Chem. Ind." 1885, iv. 633.

Digitized by Google

Should, however, an insufficiency of water be present, the hydrosulphide $Ca<^{HS}_{HS}$ is formed, which is inactive with carbon bisulphide, but is readily converted into the active hydroxy-hydrosulphide by exposure to the atmosphere, or by the passage through it of a little air, when the heat generated by the oxidation of a small portion of the material liberates the excess of sulphuretted hydrogen. Unstable basic thiocarbonates of calcium are formed with the liberation of sulphuretted hydrogen, by the action of carbon bisulphide upon the hydroxy-hydrosulphide in accordance with the following equations:

$$2\,Ca<^{SH}_{OH} + CS_2 = Ca\,H_2O_2 \cdot Ca\,CS_3 + H_2S, \text{ and}$$

$$3\,Ca<^{SH}_{OH} + CS_2 + OH_2 = 2\,CaH_2O_2 \cdot Ca\,CS_3 + 2\,H_2S.$$

These are soluble in water, forming a red liquid, part of which drains from the bottom of the boxes, and are very unstable compounds, decomposed by sulphuretted hydrogen, and more readily by carbonic acid, carbon bisulphide being liberated in both cases.

CHAPTER XV.

Purification in Closed Vessels, and Purifying Materials.

It has long been known that the methods of purification detailed in the last chapter leave much to be desired. The labour attendant upon emptying and refilling the foul purifiers; the pollution of the atmosphere by the escape of unpurified gas when the cover is lifted, and by the spent material; the necessary waste of coal-gas, and the introduction of air when a clean box is put into action, are evils which gas managers are very desirous to be rid of. The introduction of a little air with the gas, as previously described, has had the effect of somewhat ameliorating them; whilst, with the same view, Wanklyn and Cooper proposed to mix lime with the coal, and charge the retorts with the mixture. By this means a considerable portion of sulphur is arrested in the retorts, but the coke produced is of inferior quality.

Complete purification of the gas in closed vessels, such as are now used for the removal of the ammonia, has long been aimed at; but, up to the present, with only partial success.

Sulphurous acid decomposes sulphuretted hydrogen whenever the two gases are brought into contact, sulphur being deposited, and thionic acids produced; consequently sulphurous acid has often been looked to as a means of purifying coal-gas. Marriott obtained a patent for its application, but a lengthened trial of his process at the Birmingham Gasworks was unsuccessful.

Laming took out a patent for removing the carbonic acid from gas by means of ammonia, or a liquor containing salts of ammonia, but capable of absorbing more. He applied the liquor in a scrubber filled with coke, brickbats, coarse gravel, or other similar material, over which the ammoniacal solution was allowed to trickle in a thin stream, meeting the current of gas as it ascended. The sulphuretted hydrogen was subsequently removed by oxide of iron. A foreign patent was also secured by Newton in this country, for employing ammonia in a scrubber to remove both carbonic acid and sulphuretted hydrogen, and subsequently washing the gas with water to remove the ammoniacal salts. Sulphurous acid is also claimed in this patent for assisting the ammonia in removing the sulphuretted hydrogen.

Digitized by Google

R. H. Patterson likewise proposed the use of alkaline solutions for removing carbonic acid and sulphuretted hydrogen, and to restore the efficiency of the solution by treating it with lime; whilst Hills was successful in using ammoniacal liquor rendered caustic by heating almost to boiling point, a temperature sufficient to separate the acid gases from their combination with ammonia, most of which, owing to its great solubility in water, remains in solution. Thus the same liquor can be used repeatedly, loss of ammonia being avoided by passing the acid gases, on their way to the chimney stack, oxide purifier, or Claus kiln, through a tower scrubber supplied with a constant stream of clean cold water. The practicability of thus decarbonating and desulphurising gas liquor forms the basis of a very important process devised by Claus, by which for the first time the possibility of effecting almost complete purification in closed vessels has been demonstrated.

A full description of the process, as applied on a large experimental scale at the Windsor Street works of the Birmingham Corporation, was given by Mr. Charles Hunt (Trans. of the Gas Institute, 1886, p. 34) and Mr. C. W. Watts ("Journ. Soc. Chem. Ind.," 1887, p. 25).

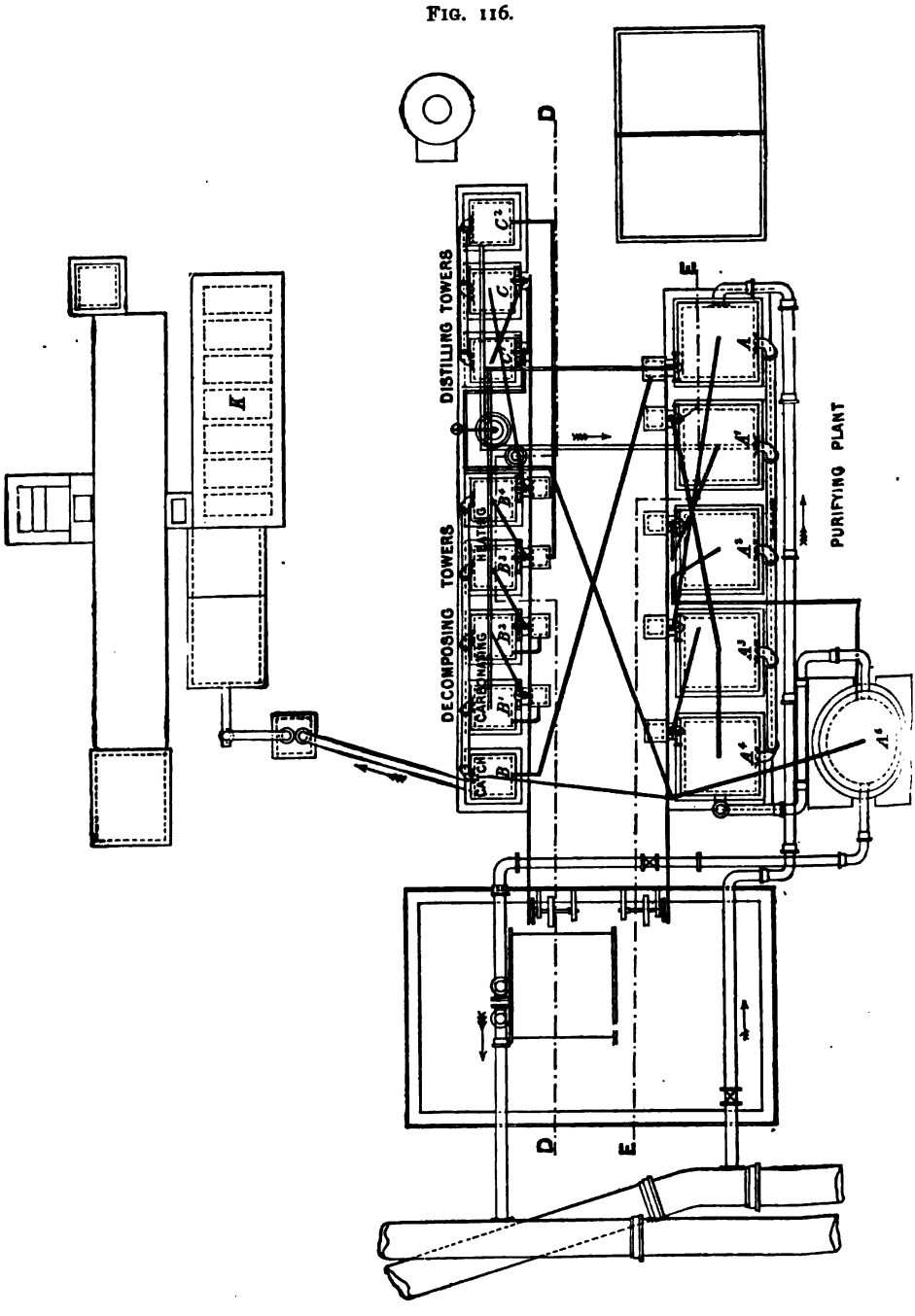
Three distinct operations are involved: (1) The purification of the gas by means of the ammonia obtained from it; (2) the decomposition of the liquor formed in the first operation, with liberation of carbonic acid and sulphuretted hydrogen, which are passed on to a Claus kiln; and (3) the distillation of the solution of ammonia left in the second operation, with liberation of NH_3, ready for use again for the first operation.

(1) A to A^5, Fig. 116, represents the plan, and Fig. 118 the elevation of the scrubbers used in the first operation which are filled with broken ganister. Coal gas containing about 4 per cent. of carbonic acid and sulphuretted hydrogen, 0·65 per cent. of ammonia, and 40 grs. of sulphur compounds other than sulphuretted hydrogen per 100 cubic feet, was completely freed from these impurities, with the exception of about 17 grs. of the sulphur compounds other than SH_2, in the following way. The gas was passed upwards through each of the scrubbers in succession, commencing with A; whilst cooled spent liquor from the still C_2 was pumped over scrubber A^5, removing the last traces of ammonia, &c., from the gas; from the bottom of this vessel it was pumped to the top of A^1, where it met with the gas—already passed through A, where the bulk of the carbonic acid was removed—and also with the gaseous ammonia coming from the still. The liquor, therefore, by the time it reached the bottom of A^1, had absorbed a considerable quantity of ammonia, and had consequently removed the bulk of the sulphuretted hydrogen from the gas. This liquor was now brought into contact with solid sulphur, by which means a quantity of ammonium bisulphide was produced, and then passed down the scrubbers A^4, A^3, and A^2 in succession, in which it removed the carbon bisulphide from the gas, and finally down A, in which it removed the bulk of the carbonic acid, with consequent liberation of a quantity of sulphuretted hydrogen.

(2) From the bottom of scrubber A the liquor, which was of about 21-oz. strength, was pumped to the decomposing plant, Figs. 116 and 117, B to B^4. Here it was treated as in Hills' process, advantage being taken of the enormously greater absorptive power which water possesses for ammonia than for carbonic acid and sulphuretted hydrogen, to expel these acid gases and at the same time retain the ammonia. It was passed in succession down through the towers B^1 to B^4, gradually acquiring an increased temperature, due to the towers B^3 and B^4 being fitted up with a number of trays containing coils of pipe, through which steam was passed, whilst the liquor fell from tray to tray. The acid gases which were expelled by the heat were passed through the towers in the opposite direction to the liquor, finally escaping

Digitized by Google

FIG. 116.

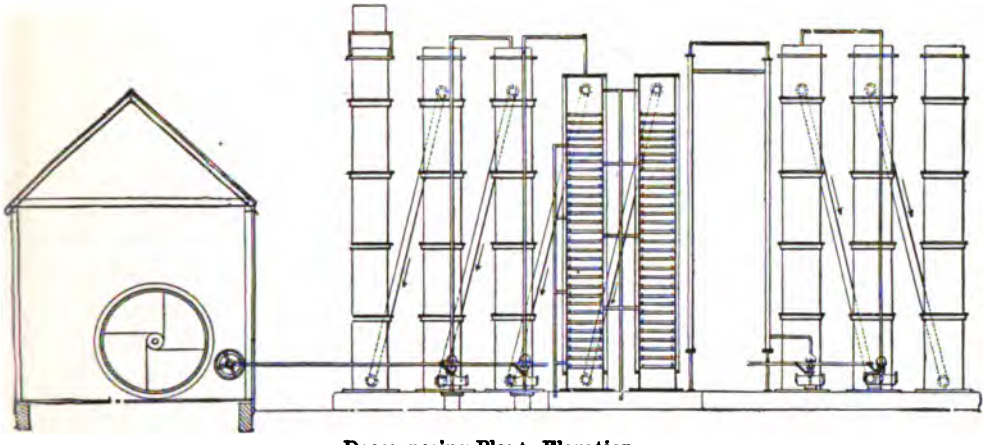


Plan of Purifying Plant.

Digitized by Google

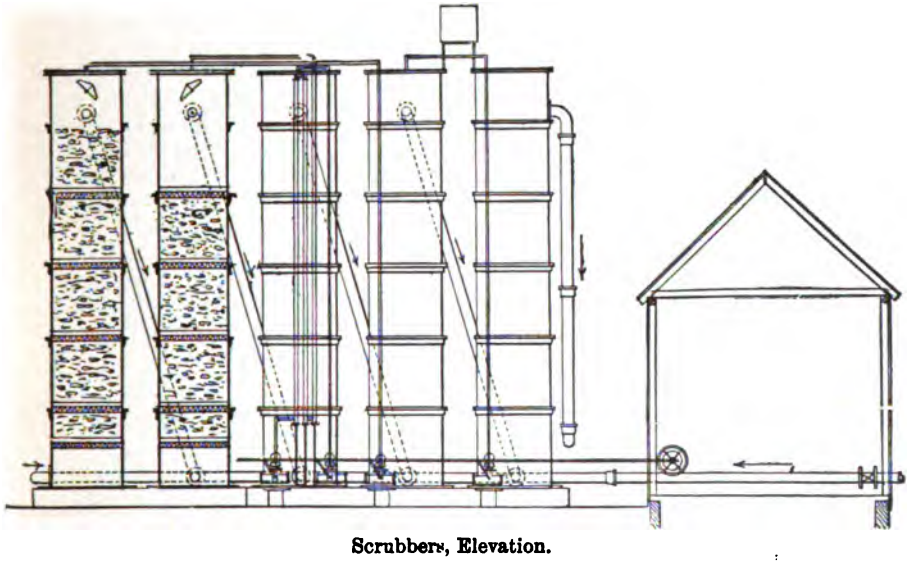
by tower *B*, down which cooled spent liquor was run to remove all traces of ammonia, and although some of the ammonia was expelled by the heat and passed along with them, it was continually brought back by the incoming cool liquor. At the bottom of the tower B^2 it was found that the liquor

FIG. 117.



Decomposing Plant, Elevation.

FIG. 118.



Scrubbers, Elevation.

had lost all sulphuretted hydrogen, and that the excess of ammonia above that required for purifying the gas—which excess is due, of course, to the continuous incoming of ammonia in the crude coal gas—could here be withdrawn in the form of carbonate. Or, if desired, the surplus ammonia may be withdrawn from the scrubber *A* as ammoniacal liquor; or, an acid saturator may be substituted for the tower *B*, and sulphate of ammonia made.

The acid gases (CO_2 and H_2S) were passed from the top of the wash-

Digitized by Google

tower *B* to a Claus kiln *K*. This consisted of a small chamber lined with fire-brick, containing a layer of lump oxide of iron, down through which the gases, mixed with air, equal in volume to 2½ times the quantity of sulphuretted hydrogen present, were caused to pass. The sulphuretted hydrogen and the oxygen in the air supplied, in passing through the oxide of iron, which is maintained at a red heat by the reaction, combined to form water and sulphur, both of which were necessarily in a vaporous condition. These, together with the carbonic acid, then passed through a large chamber with transverse baffle walls, where the sulphur was deposited. Any sulphurous acid or sulphuretted hydrogen, which might be present owing to an excess or deficiency of air, was arrested by means of a small wash-tower and an oxide of iron purifier.

(3) The caustic ammonia liquor obtained from the base of B^4 was pumped to the still *C*, C^1, C^2, in which gaseous ammonia is expelled from the liquor and conducted to the top of scrubber *A* of the purifying plant.

In addition from the spent liquor, after driving out the fixed ammonia, ferrocyanogen and sulphocyanogen were recovered.

This process was applied at the Belfast Gas Works for the treatment of about 2,000,000 cubic feet of gas per diem.

Mr. T. Holgate has had considerable success at Halifax in the use of purified gas liquor as an aid to gas purification.

In a paper read before the Incorporated Institution of Gas Engineers (Trans. Vol. v. p. 222), after alluding to the processes of Hills and Claus, he thus describes the apparatus and method of working which he has adopted :—

"The features in them (*i.e.* the Claus and Hills processes) which appear unsatisfactory are the following: (*a*) loss of ammonia; (*b*) costly nature of plant; (*c*) the great care required in working.

"The aim of the author has been to obtain the advantages by a simple method, while avoiding the drawbacks above mentioned; and to describe such method is the object of this paper. The principle of its operation is that already well-known; namely, the heating of ammoniacal liquor to a temperature of about 200° F., whereby the greater part of the carbonic acid and sulphuretted hydrogen is driven off, whilst the bulk of the ammonia is retained. The gases thus driven off are passed into a saturator, such as is used in the manufacture of sulphate of ammonia, the NH_3 is absorbed by acid, whilst the H_2S and CO_2, together with the steam, pass into the ammoniacal liquor heater, and from thence into an oxide of iron purifier, a Claus kiln or sulphuric acid plant. The heating of the ammoniacal liquor may be effected by a separate source of heat, preferably live or exhaust steam, or by the waste gases from a sulphate of ammonia plant, which latter plan has been adopted in the plant designed and worked by the author. The following is a description of its construction and mode of working :—

"The hot waste gases from the saturator pass through a 12-inch pipe and enter at A the upper half of a vertically placed vessel—shown in the figure as No. 1 (Fig. 119)—and flow downwards to the base of the tower, passing thence at F to a condenser for further cooling, and on to the Claus kiln.

"This tower contains within it two coils of pipe, one long and one short, through which flows the ammoniacal liquor undergoing purification. The liquor enters at the bottom of each coil and emerges at the top (B) upon a series of trays, in a compartment which communicates by means of an eight-inch pipe with another leading to the saturator of the sulphate still. The gases driven off are returned, after abstraction of the NH_3 which they contain, to give up their heat upon the outside of the coils through which the streams of liquor are flowing from which they emanate.

"The ammoniacal liquor, which has been deprived of the greater part of

Digitized by Google

its H_2S and CO_2 passes at C from the bottom of the upper compartment of tower No. 1 into the lower half of the vessel shown as tower No. 2, at the point marked D.

" Inside this part of tower No. 2 is a third coil of pipes, through which

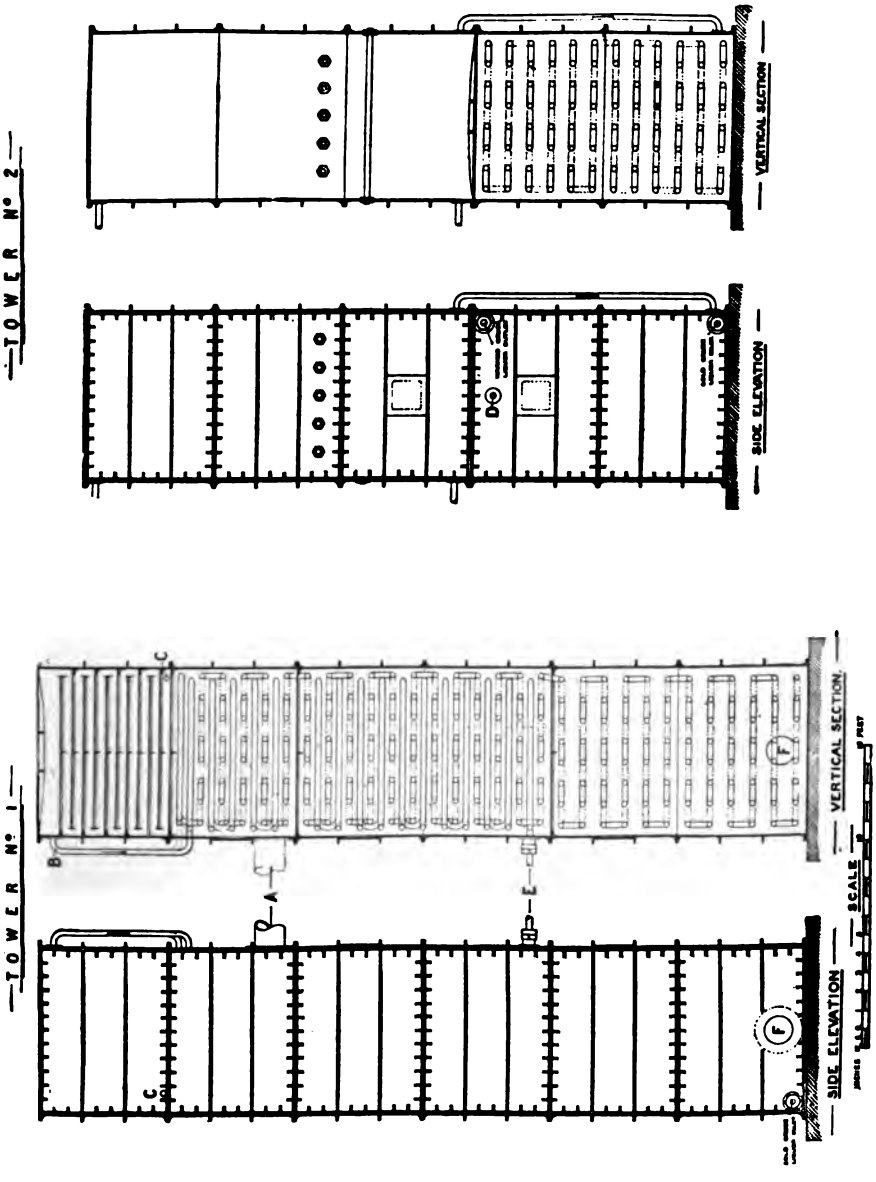


FIG. 119. Holgate's Ammoniacal Liquor Purifier.

the second stream of ammoniacal liquor undergoing purification passes. This impure liquor receives its first heating from the hot purified liquor which is passing to the washer; and on emerging from tower No. 2 this second stream flows through the short coil already mentioned in tower No. 1, entering the latter at E. The heating of the impure ammoniacal liquor in

Digitized by Google

tower No. 2 at the same time effects the cooling to a considerable extent of the purified liquor. To more efficiently cool the latter it must be passed through a tubular water or other condenser, or through a series of vertical cast-iron pipes, as at the Halifax Gasworks.

"The quantity of liquor flowing through each of the coils is most easily regulated by valves, and thus the required temperature of the liquor flowing on to the trays is obtained without difficulty.

"The upper part of tower No. 2 receives the partially-cooled purified liquor from the base of the tower No. 1, and serves as a store for the liquor flowing to the washer.

"The following are tests of liquor before and after purification :—

Before Purification.					After Purification.					Reduction in Density.	Impurities removed per cent.			
Density.	NH_3	CO_2	H_2S	Total.	Density.	NH_3	CO_2	H_2S	Total.		NH_3	CO_2	H_2S	Total.
3½° T.	1.343	—	—	1.76	1½° T.	0.986	—	—	0.528	2° T.	26.5	—	—	70.0
4° T.	1.327	—	—	1.554	1½° T.	1.053	—	—	0.546	2½° T.	20.6	—	—	65.0
4° T.	1.360	2.18	0.50	2.68	2° T.	1.13	.99	0.08	1.07	2° T.	16.9	54.5	84.0	60.0

"The following tests of gas at No. 2 works show the effect of washing with unpurified and purified liquor in a washer 10 ft. × 12 ft. × 20 ft., having seven seals, each 1½ inch deep :—

	Unpurified Liquor Used.			Purified Liquor Used.		
	CO_2.	H_2S.	Total.	CO_2.	H_2S.	Total.
Inlet gas	3.374	1.660	5.034	2.748	1.425	4.173
Outlet gas	2.796	1.428	4.224	1.687	0.825	2.512
Difference . . .	0.578	2.32	0.810	1.061	0.600	1.661
Per cent. . . .	17.13	14.00	16.1	38.6	42.1	39.8
Liquor used . . .	At 73° F. raised from 4½° Tw. to 5½° Tw.			At 82° F. raised from 1½° Tw. to 2½° Tw.		
Gas passed . . .	64,000 cubic feet per hour at 58° F.			68,000 cubic feet per hour at 62° F.		

Statement of Lime and Oxide Boxes Changed.

I. WHEN WASHING GAS WITH UNPURIFIED LIQUOR.

Works.	No. of Changes.		Gas passed in Thousands	No. of Days.	Gas passed in Thousands.			
	Oxide.	Lime.			Per Day.	Per Change.		—
						Oxide.	Lime.	
No. 1 .	2	8	10.521	27	390	5,260	1,315	(*a*)
No. 2 .	18	14	93,914	51	1841	5,217	6,708	(*b*)
Total .	20	22	104,435	—	—	5,222	4,747	—

(*a*) From February 28 to March 27, 1895; (*b*) From November 25 to December 19, 1894, and February 28 to March 27, 1895.

Digitized by Google

Statement of Lime and Oxide Boxes Changed.

II. WHEN WASHING GAS WITH PURIFIED LIQUOR.

Works.	No. of Changes.		Gas passed in Thousands.	No. of Days.	Gas passed in Thousands.			
	Oxide.	Lime.			Per Day.	Per Change.		—
						Oxide.	Lime.	
No. 1 .	9	12	47,771	74	646	5,308	3,906	(*c*)
No. 2 .	18	26	219,010	112	1955	12,167	8,416	(*d*)
Total .	27	38	266,781	—	—	9,881	7,021	—

(*c*) January 1 to February 28, and March 27 to April 11, 1895; (*d*) From November 6 to 25, 1894; December 19, 1894, to February 28, 1895; March 27 to April 18, 1895."

Purifying Materials.

Oxide of Iron.—The estimation of the quantity of oxide of iron in a sample by the ordinary well-known methods is valueless as a means of distinction between a good and bad purifying material; an oxide may contain 90 per cent. of ferric oxide and be inferior to one containing but 50 per cent. The explanation is that the ferric oxide exists in two forms—"active" and "inactive."

Mr. H. Leicester Greville proposes the following as a means of estimating the amount of active ferric oxide in a purifying material:—

"Place a weighed quantity of the dried and finely-powdered sample of oxide in a U-tube (preferably mixing it with some dry neutral material, such as sawdust or cocoanut fibre refuse), then connect this tube to a carefully weighed calcium chloride tube, and pass a current of dry sulphuretted hydrogen until the oxide is saturated. The calcium chloride tube is then detached, a little dry air passed to displace the sulphuretted hydrogen, and finally weighed. The increase of weight divided by four will give the amount of water present in combination with Fe_2O_3 in the sample taken. As one molecule of Fe_2O_3,H_2O in reaction with H_2S gives four molecules of water, the weight of the molecule Fe_2O_3,H_2O—viz., 178—will give 72 parts by weight of water; and each part of water obtained will represent 2.472 parts of Fe_2O_3,H_2O."

Spent Oxide of Iron.—The quantity of free sulphur present in a purifying material, spent or partially spent, is usually ascertained by treating it with carbon bisulphide, to dissolve out the sulphur, evaporating the carbon bisulphide, and weighing the residue of sulphur.

Fifty grains of the material are weighed in a watch-glass, and dried in a water-oven at 100° C. (212° F.) until the weight is constant. The loss in weight may be considered as moisture. It is now treated successively with small quantities of carbon bisulphide (free from sulphur), which are then filtered through a small filter-paper into a weighed flask. The treatment is continued until no more sulphur is dissolved out, this being ascertained by evaporating a small quantity of the carbon bisulphide with which the material has been treated, to dryness on a watch-glass, when no residue should be left. The flask containing the carbon bisulphide and sulphur in solution is connected to a condenser, and the carbon bisulphide distilled off

Digitized by Google

by heating the flask in a water-bath. The flask is placed in a water-oven at 100° C. (212° F.) for a few hours, then allowed to cool, and weighed. The increase in weight of the flask equals the free sulphur in 50 grains.

Lime.—The purity of lime may be quickly determined by the following method. A sample is carefully taken from the bulk, and a weighed quantity triturated in a mortar with a little water until no coarse particles remain. The mixture is then washed out into a beaker and boiled, a little phenol-phthaleïn added, and standard acid run in until the red coloration is just discharged, which occurs when the hydrate is saturated (the carbonate, when present, being rendered dense by boiling, remains neutral to the indicator). An excess of the acid is then added, and the mixture re-titrated with standard alkali until the red coloration again appears; this gives the quantity of carbonate of lime present. The original quantity taken, minus the calculated quantity of lime and carbonate of lime, gives the weight of impurities present.

Spent Lime.—The above method may be used for testing lime after it has been used in the purifiers for extracting the carbonic acid from the gas, the quantity of moisture present in the sample having first been ascertained.

The amount of hydrate left in spent lime may also be ascertained by washing a weighed quantity of the undried lime into a flask of known capacity, adding a little of a saturated solution of ammonium chloride and filling the flask up to the mark with water. It is left for two or three hours, being occasionally shaken, and then allowed to get clear. An aliquot portion is withdrawn and titrated with standard acid.

The efficiency of lime for gas purification varies greatly, being dependent on its freedom from argillaceous earth. It may be accepted as a general rule that quicklime, which increases to about twice its original volume when slaked ready for the purifiers, will purify fully 11,000 cubic feet of gas per bushel (about 70 lbs.). This is of course influenced by the amount of impurities in the gas, and to some extent by the manner in which the lime is prepared. It should be slaked with clean water a day or two before it is required for use, and should not be placed in the purifiers unless thoroughly moistened. The following table, by Mr. Theobald Forstall,* an American engineer, indicates a remarkable diversity of results from the observance or otherwise of this necessary condition :—

Year.	Average daily production for December.	Number of Layers of Lime worked through.	Total thickness of Lime.	Maximum pressure at inlet of Purifiers.	Mean pressure at outlet of Purifiers.	Cubic Feet of Gas purified per bushel of unslaked Lime in December.	Cubic Feet of Gas purified per bushel of unslaked Lime for the whole Year.	Condition of Lime.
	Cubic Feet.		Inches.	Inches.	Inches.			
1870	969,000	6	12	18	5	7,752	9,053	Dry
1871	1,010,000	9	27	13	5	11,222	10,000	Dry during half the year
1872	1,067,000	9	36	15	5	11,854	11,807	Wet
1873	993 800	9	54	17	5	22,084	17,291	Wet

As the result of actual experience Mr. Forstall concludes :—

* *Journal of Gas Lighting, &c.*, xxvi. p. 364.

Digitized by Google

"1.—That the granulated hydrate, containing as much water as it can be made to retain without becoming adhesive under careful handling, will purify a much greater quantity of gas per bushel than when in the dry and almost dusty state in which it is generally employed.

"2.—That in the former condition it offers less resistance to the free passage of the gas through the purifiers.

"3.—That numerous thin layers of lime can, therefore, be advantageously consolidated into a lesser number of greater thickness, with economy of labour and wear and tear."

Mr. F. Egner, another American engineer, also states that he is able to purify about 22,000 cubic feet of gas per bushel of unslaked lime by preparing the latter in thin layers, well watering, and mixing with about one-tenth of its bulk of unscreened coke breeze.

Hislop's patent process meets the difficulty as regards its disposal where lime is used for removal of carbonic acid. The spent lime (calciun carbonate) is decomposed in chambers heated by producer furnaces; carbonic acid is thus expelled, and the lime, after treatment with water, is ready for reuse. At the Paisley Gasworks lime has been used after the 100th restoration. Mr. W. Stokes brought under the notice of the Institution of Gas Engineers in 1891 (Transactions, p. 120), an inclined revolving furnace, for effecting more rapidly the decarbonating of spent lime, which has since been successfully applied.

CHAPTER XVI.

Analysis of Gas Before and After Purifiers.

Unpurified Gas.—There are many methods of ascertaining the amount of sulphuretted hydrogen and carbonic acid in the unpurified coal gas, one of the most accurate of which is founded upon the increase in weight of absorption tubes—a method which has been much improved by Mr. Lewis T. Wright. He adopts as the reagent for the absorption of sulphuretted hydrogen cupric phosphate, which may be prepared in the following manner:

A solution of 2 lbs. of hydrogen sodium phosphate (Na_2HPO_4) in one gallon of water is mixed with a solution of $2\frac{1}{2}$ lbs. of copper sulphate in $1\frac{1}{2}$ gallons of water and well stirred—the bright blue precipitate thus produced is washed by decantation and then dried in a water bath at about 212° F. (100° C.).

The absorption tubes used are preferably U-tubes with hollow glass stoppers serving as stopcocks, a plug of cotton wool being placed in the hollow of each stopper.

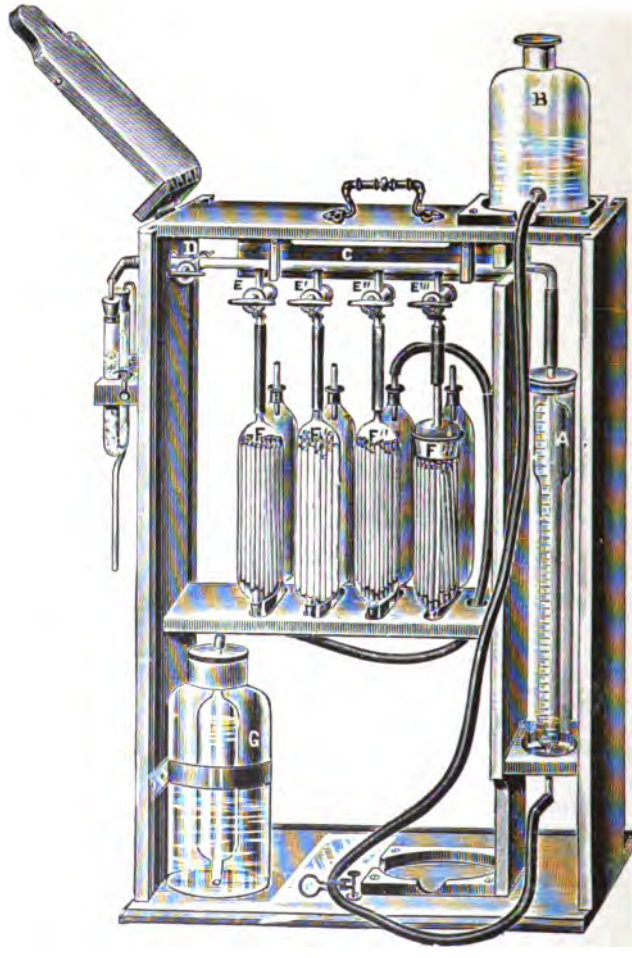
In making an estimation, the gas is taken from a service through which a rapid current is passing. If the gas contains ammonia, this is first removed by passing it through a 12-inch U-tube, containing small pieces of pumice saturated with syrupy phosphoric acid. It is next passed through a drying cylinder filled with lumps of calcium chloride and then through a 6-inch U-tube, the first limb of which contains the cupric phosphate, the other being filled with calcium chloride. This tube should be weighed previously, but before doing so, about 3 cubic feet of *clean* dry coal gas must be passed through it, as it is found that the phosphate at first gains a little in weight when exposed to the action of clean coal gas. The gas next passes into another 6-inch U-tube, which has been weighed after displacing the air by clean coal gas; the first limb of this tube is filled with soda lime (which combines with the carbonic acid), previously exposed to a moist atmosphere for from 12 to 18 hours, and the other limb with calcium chloride. A test gas meter connected to the outlet of the soda lime tube completes the

Digitized by Google

apparatus. After the required volume of the impure gas has passed, a current of dry clean coal gas is sent through the phosphate and soda lime tubes, which are then weighed. Each 6-inch U-tube is capable of absorbing from 15 to 18 grains of the impurity which it takes up.

The results obtained by this method are slightly high on account of the

FIG. 120.



Orsat-Muencke Apparatus.

absorption of the cyanogen contained in the unpurified gas, which, however, rarely exceeds 1 grain per cubic foot.

The Orsat-Muencke gas analysis apparatus* is very suitable for determining the impurities in coal-gas, combining as it does simplicity of manipulation with a considerable amount of accuracy.

This apparatus (Fig. 120) is applicable for the estimation of the absorbable constituents of such gaseous mixtures as crude coal-gas, water gas, furnace and chimney gas, &c.

* This, as well as other apparatus mentioned, may be obtained of Messrs. P. Harris & Co., Edmund Street, Birmingham.

Digitized by Google

It consists of a measuring tube, A, graduated into $\frac{1}{10}$ c.c. This tube, which is surrounded by a water-jacket for the maintenance of a constant temperature, is connected at the bottom by means of indiarubber tubing with the levelling bottle B, which should be about two-thirds filled with water.

The upper capillary end of A is connected by means of thick walled tubing to one end of the capillary tube C, the other end of which is furnished with a three-way stopcock, D. Three (or if required more) stopcocks E, E′, E″, are fused on at right angles to the capillary tube C, and communicate by means of thick-walled tubing with the absorption pipettes F, F′, F″. The latter are U-shaped vessels, having the compartments attached to the stop-cocks filled with thin walled glass tubes, for the purpose of exposing a large surface of the absorbent when gas is admitted. The pipettes are filled with such absorbent liquids as are required for the gas which is to be analysed; for instance, with unpurified coal-gas, F may be filled with a 20 per cent. solution of cadmic chloride, which will remove all the sulphuretted hydrogen, F′ with a 50 per cent. solution of caustic potash for the removal of carbonic acid, and F″, with a mixture of two parts by volume of a 50 per cent. solution of caustic potash and one part of a 20 per cent. solution of pyrogallic acid for the absorption of oxygen. Enough of the absorbent must be used to rather more than fill that limb of the pipette which contains the tubes; and this will be found sufficient for about 100 analyses.

It is necessary to protect the pyrogallate of potash from the oxygen of the atmosphere, which may be done by connecting the open limb of the pipette F″, by means of thick-walled tubing to the vessel G, which cuts off communication with the atmosphere by means of a water-seal. The air at first contained in G is speedily deprived of its oxygen, and no further deterioration of the absorbent can take place from this source.

A fourth stop-cock and absorption pipette to contain Nordhausen acid may be employed for the estimation of heavy hydrocarbons (benzene, ethylene, &c.).

For the analysis of chimney and furnace gases, F should be filled with the caustic potash solution for CO_2, F′ with pyrogallate of potash for O_2, and F″ with a strong solution of cuprous chloride* in hydrochloric acid for the absorption of carbonic oxide. It is well to have a fourth pipette also filled with cuprous chloride for treating the gas after the bulk of the carbonic oxide has been removed in F″. Pipettes containing cuprous chloride should be filled with copper wire spirals instead of glass tubes, and must be connected to the vessel G, so as to protect the absorbent from the atmosphere.

The absorbents should just reach to the under parts of the stopcocks E, E′, E″, with the exception of Nordhausen acid, which should stand in the capillary tube of the pipette at a mark made a short distance below the connecting tubing.

Manipulation.—To fill the measuring tube A with the gas to be analysed, place the levelling bottle B on the top of the case, and turn the stopcock D, so as to put the measuring tube in communication with the atmosphere. As soon as the water reaches the top of A (it should never enter the capillary C) cut off the communication at D. Then if the gas to be examined be under pressure, connect the end of the capillary tube C with the source of supply, and allow the gas to blow through the side opening of the three-way stopcock D,

* Cuprous chloride may be readily prepared by adding about 2 ozs. of common salt to a boiling saturated solution of about 4 ozs. of copper sulphate, containing a few strips of copper. The mixture should be allowed to settle, and the liquid poured off into a large quantity of water (1 gallon), which precipitates the cuprous chloride. This should stand over-night, the water syphoned off, and the cuprous chloride dissolved in the minimum quantity of strong hydrochloric acid.

Digitized by Google

to displace the air in the connecting tubing. Turn the stopcock D so as to put the gas supply in communication with the measuring tube A, lower the levelling bottle B until the gas fills the tube to a little below the zero graduation, and then close the stopcock D.

In case the gas should not be under pressure, it will be necessary to displace the air in the connecting tubes by means of a small indiarubber aspirator placed in connection with the side opening of the stopcock D. When this is done the measuring tube may be filled as before.

Now raise the levelling bottle B until the gas is compressed and the water rises in the measuring tube to a little above the zero graduation. Put a pinchcock on the connecting tube, place the levelling bottle on the working bench, and cautiously open the pinchcock until the bottom of the water meniscus just touches the zero graduation. Then momentarily pull out and replace the plug of the stopcock D, and there remains exactly 100 c.c. of the gas at the prevailing atmospheric pressure.

To analyse the gas, place the levelling bottle B on the top of the case, remove the pinchcock from the connecting tube, and open the cock E, when the gas will pass into the absorbing pipette F. When it has all passed in, lower the levelling bottle B until the absorbing liquid in F nearly reaches the stopcock E; then put B again on the top of the case, to force the gas once more into the pipette F. Now cautiously lower the levelling-bottle B with the right hand, and shut the stopcock E with the left as soon as the absorbent reaches its underside.

Upon holding the levelling bottle B at the back of the measuring tube A, so that the water is at the same level in both, the diminution in volume of the gas may be read off. This represents the percentage of that constituent of the gas analysed which can be absorbed by the liquid in F, *i.e.*, CO_2.

The whole operation can be performed with great ease in a few minutes. It will be found that three passages of the gas into each absorbing pipette is sufficient, with the exception of the cuprous chloride pipette, as the removal of carbonic oxide requires rather longer treatment.

After using the Nordhausen acid and cuprous chloride pipettes, the gas must be passed once or twice into the caustic potash pipette to remove acid fumes before it is measured.

Should there be any tar or soot in the gas to be examined, a small U-tube containing a plug of cotton wool should be inserted between the apparatus and the source of gas supply.

All the stopcocks should be kept well lubricated with vaseline or resin cerate, or, better, with a mixture of 2 parts of caoutchouc and 1 part of vaseline, made by melting the caoutchouc in a covered crucible, adding the vaseline, and stirring until the mixture is cold.

The sulphuretted hydrogen present in impure gas can be rapidly estimated by means of a standard solution of iodine (centinormal is a convenient strength, 1 c.c. being equal to 0.0026234 grain SH_2).* There are many methods of making the tests, one of which is to collect the gas in a glass bottle of known capacity (say 1000 c.c.), provided with an india-rubber bung through which glass inlet and outlet tubes, fitted with stopcocks, are passed. A little caustic potash solution is then run in and the bottle shaken. It is afterwards washed out either into a beaker, the whole of the washings being used; or into a 500 c.c. flask, which is then filled up to the mark with water and from which 100 c.c. at a time may be withdrawn for analysis. The caustic potash present must be just neutralised with dilute acid, a little starch solution added, and the standard iodine

* The methods employed in preparing standard solutions of iodine will be found described in works on chemical analysis. Suttons "Volumetric Analysis" or Thorpe's "Quantitative Chemical Analysis" will be found useful.

Digitized by Google

run in until the characteristic blue coloration of iodide of starch is produced.

It is better, however, to run the caustic potash solution into an excess of the iodine solution, to which a sufficiency of acid has been added to rather more than neutralise the alkali, and then to determine the excess of iodine by means of a standard solution of sodium thiosulphate.

Very accurate determinations of sulphuretted hydrogen may be made by means of a Bunte burette and a standard solution of iodine. 100 c.c. of the gas to be analysed is measured in the usual way (*vide* page 139), the water withdrawn from the burette, and an excess of iodine solution added. The burette and its contents are then well shaken, and the solution washed out into a porcelain dish; the excess of iodine being determined by means of starch and standard thiosulphate.

Carbonic acid may be determined after the removal of sulphuretted hydrogen by passing a definite volume of the coal gas through a solution of

FIG. 121.

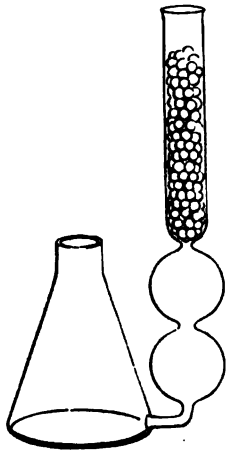
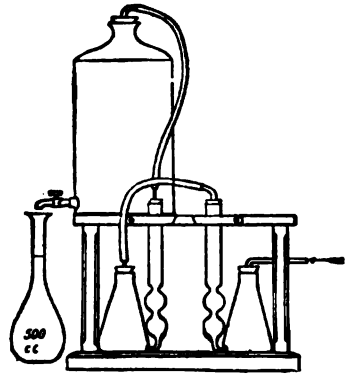


FIG. 122.



Sheard's Carbonic Acid Apparatus.

barium hydrate of known strength, the excess of hydrate being afterwards determined by standard oxalic or hydrochloric acid, decinormal being a convenient strength.

Figs. 121 and 122 represent a convenient apparatus devised by Mr. J. T. Sheard.

To make a test, 20 or 30 c.c. of the solution of barium hydrate is run in on to the glass beads contained in the straight tube above the bulbs. The apparatus is then connected as shown in Fig. 121, and, by means of the aspirator, 500 c.c. of gas are drawn slowly through it, followed immediately, without stopping the current, by an equal quantity of air, which is done by slipping off the india-rubber tube at the inlet of the apparatus as the water running from the aspirator reaches the 500 c.c. mark, and then running out a further 500 c.c. into another flask. The beads are then washed down with distilled water free from carbonic acid, a few drops of a solution of phenol-phthaleïn added, and the standard hydrochloric acid run in until the purple coloration, produced by the phenol-phthaleïn, is just discharged.

The strength of the barium hydrate solution may be ascertained by performing a blank experiment, that is by running a known quantity of the

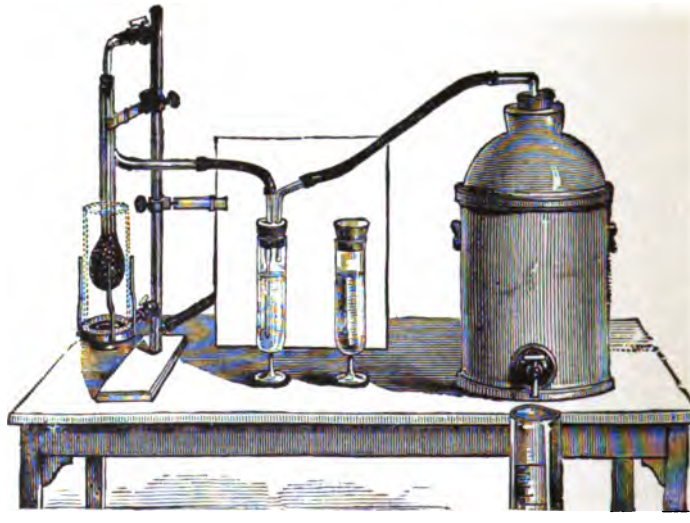
Digitized by Google

solution into the two absorption tubes, passing 500 c.c. of air only, and then titrating with the standard acid. The strength of the barium hydrate solution remains constant for a long period if care be taken to use a solution which is not completely saturated, and to preserve it from contact with the atmosphere.

Mr. C. W. Folkard has devised a simple and expeditious method of estimating the carbonic acid, and one which is well adapted for use in the purifying house.

A glass bottle of known capacity, fitted with an india-rubber bung, is used. Through a hole in the bung a small test tube is passed into which a known quantity of a solution of barium hydrate is run. The bottle is filled by upward displacement with the gas to be tested, the bung inserted and the whole arrangement shaken. In a few minutes the solution of barium

FIG. 123.



Harcourt's Carbon Bisulphide Apparatus.

hydrate will have combined with all the carbonic acid present, when the excess of hydrate may be determined by standard acid, using phenol-phthaleïn as an indicator, as described in the previous method. Solutions of the same strength may be used.

In both these methods, it is necessary to first remove the sulphuretted hydrogen, if any be present, by means of an oxide of iron purifier. The gas should be passed for about half an hour through the small oxide purifier before making a test.

Harcourt's colour test is very generally used in gas-works for the estimation of the carbon bisulphide present in the gas. If it be desired to ascertain its amount before the gas is completely purified, the sulphuretted hydrogen must first be removed by passing the gas through a small oxide purifier.

The arrangement of the colour test is shown in Fig. 123, the chimney of the burner being represented by dotted lines. The bulb, which is filled with platinised pumice, is adjusted so that it may be about an inch above the burner and in the middle of the chimney.

Digitized by Google

To use the apparatus, turn on first the upper stopcock, sending gas through the bulb at the rate of about half a cubic foot an hour, as may be judged by lighting the gas for a moment at the end of the horizontal arm, when a flame about an inch in length should be produced. Light the burner, and turn down the flame till it forms a blue, non-luminous ring, then place the small clay-pieces upon the top of the chimney round the neck of the bulb.

A test may be made five minutes after lighting the burner, except when the apparatus is first used, when the gas should be allowed to flow through the bulb for a quarter of an hour, or a little longer, and any number of tests may be made one after another, as long as the heat is continued.

The mode of testing is as follows:—Lay a piece of white paper on the table by the side of the burner, and fix a piece of cardboard upright in the brass clip; the cardboard serves as a background against which to observe the colour of the contents of the glasses, and should receive a side light, and be as clear as possible from shadows. Fill one of the glasses up to the mark with standard coloured liquid once for all, and cork it tightly.* Prepare a lead syrup by dissolving litharge in caustic potash and mix this solution with a dilute solution of sugar; dilute some of this lead syrup with about twenty times its volume of distilled water, and fill the other glass up to the mark with a portion of the liquid thus prepared. Insert the caoutchouc plug with capillary-tube and elbow-tube,† and connect, as shown in the figure, with the bulb and aspirator, placing the two glasses side by side.

The aspirator must be quite full of water at starting, and the measuring cylinder empty. Turn the tap of the aspirator gradually; a stream of bubbles will rise through the solution of lead. Turn off the tap for a minute, and observe the liquid at the bottom of the capillary-tube. If it gradually rises, the india-rubber connections are not air-tight, and must be made so before proceeding. Avoid pressing the plugs into the glass or the aspirator while they are connected, which would drive up the lead solution into the inlet tube. When the connections are air-tight, let the water run into the measuring cylinder in a slender stream until the lead solution has become as dark as the standard. As the ascending bubbles interfere somewhat with the observation of the tint, it is best to turn off the tap when the colour seems almost deep enough; compare the two; turn on the tap, if necessary, for a few moments; then compare again; and so on, till the colour of the two liquids is the same.

The volume of water which the measuring cylinder now contains is equal to the volume of gas which has passed through the lead solution. This volume of gas contained a quantity of sulphur as carbon bisulphide, which, as lead sulphide, has coloured the liquid in the test-glass up to the standard tint. The standard has been made such that, to impart this tint to this volume of liquid, 0.0187 grain of lead sulphide must be present containing 0.0025 grain of sulphur. Hence, supposing the measuring cylinder, each division of which corresponds to $\frac{1}{2000}$ cubic foot, to have been filled

* There are *two* standard colour solutions, one for daylight and the other for gaslight, and these can now be had in sealed glasses; the glass containing the standard should be shaken before commencing a test. These coloured liquids, which are made by mixing solutions of copper sulphate, cobalt sulphate and ferric sulphate until the desired tint and depth of colour are attained, are standardised against an equal volume of the lead syrup through which a volume of gas containing a known quantity of sulphur in the form of carbon bisulphide has been passed from a Pepys gasholder after passing over the heated platinised pumice. The amount of sulphur so contained in the gas is ascertained by passing a measured quantity over the heated pumice and then through an ammoniacal solution of arsenic from which sulphide of arsenic is afterwards precipitated by acid, dried and weighed.

† The capillary-tube should descend very nearly to the bottom of the glass, but must not press upon the bottom, or it will probably be broken.

Digitized by Google

to the 30th division, $\frac{80}{2000}$ cubic foot of gas contained 0.0025 grain of sulphur. From this ratio, the number of grains of sulphur existing as bisulphide in 100 cubic feet of the sample of gas tested can easily be calculated.

$$S = \frac{500}{V}$$

V	S	V	S	V	S	V	S
10	50.0	33	15 1	56	8.9	79	6.3
11	45.4	34	14.7	57	8.8	80	6.2
12	41.7	35	14.3	58	8.6	81	6.2
13	38.5	36	13.9	59	8.5	82	6.1
14	35.7	37	13.5	60	8.3	83	6.0
15	33.3	38	13.2	61	8.2	84	6.0
16	31.3	39	12.8	62	8.1	85	5.9
17	29.4	40	12.5	63	7.9	86	5.8
18	27.8	41	12.2	64	7.8	87	5.7
19	26.3	42	11.9	65	7.7	88	5.7
20	25.0	43	11.6	66	7.6	89	5.6
21	23.8	44	11.4	67	7.5	90	5.6
22	22.7	45	11.1	68	7.4	91	5.5
23	21.7	46	10.9	69	7.2	92	5.4
24	20.8	47	10.6	70	7.1	93	5.4
25	20.0	48	10.4	71	7.0	94	5.3
26	19.2	49	10.2	72	6.9	95	5.3
27	18.5	50	10.0	73	6.9	96	5.2
28	17.9	51	9.8	74	6.8	97	5.2
29	17.2	52	9.6	75	6.7	98	5.1
30	16.7	53	9.4	76	6.6	99	5.1
31	16.1	54	9.2	77	6.5	100	5.0
32	15 6	55	9.1	78	6.4	150	3.3

The above table gives the relation between V, the divisions of the measuring cylinder filled with water, and S, the grains of sulphur existing as bisulphide in 100 cubic feet of gas. Since gas contains besides carbon bisulphide some other sulphur compounds which are not transformed into sulphuretted hydrogen by the action of heat, and which contain sulphur amounting ordinarily to 7 or 8 grains in 100 cubic feet, this quantity must be added to that found by the test, if it is wished to know approximately the total amount of sulphur in the gas.

For the next testing, the test-glass is to be disconnected and re-charged. The water in the measuring cylinder is poured back into the aspirator.

The colour of the standard is not affected by exposure to light, but deepens if the liquid is warmed, returning to its original shade as the liquid cools. If, therefore, the glass containing the standard has been in a warm place, it must be allowed to cool before testing.

The liquid which has been used becomes colourless after being exposed to the light for a few hours, and may thus be used over and over again twenty times or more, if it is not allowed to absorb carbonic acid from the air. The best mode of working is to have two well-corked flasks, into one of which the coloured liquid is emptied, whilst the glass is re-charged from the other.

Purified Gas.—In London the whole of the gas supplied is required to be completely purified from sulphuretted hydrogen, must not contain more than 4 grains of ammonia, nor more than 20 grains of sulphur in the winter months and 17 grains in the summer months per 100 cubic feet.

The instructions of the Gas Referees as to the times and mode of testing for purity are as follows :—

"The testings for purity shall extend over twenty hours of each day, and

Digitized by Google

shall be made upon 10 cubic feet of gas, which shall be tested successively for each of the following impurities :—

"*Sulphuretted Hydrogen.*—The gas shall be passed as it leaves the service pipe through an apparatus in which are suspended slips of bibulous paper, impregnated with basic acetate of lead.

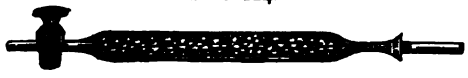
"The test-paper from which these slips are cut is to be prepared from time to time by moistening sheets of bibulous paper with a solution of one part of sugar of lead in eight or nine parts of water, and holding each sheet while still damp over the surface of a strong solution of ammonia for a few moments. As the paper dries all free ammonia escapes.

"If any discoloration of the slip of test-paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas. Fresh test-slips are to be placed in the apparatus every day.

"In the event of any impurity being discovered, one of the test-slips shall be placed in a stoppered bottle and kept in the dark at the testing-place; the remaining slips shall be forwarded with the daily Report.

"*Ammonia.*—The gas which has been tested for sulphuretted hydrogen shall pass next through an apparatus consisting (Fig. 124) of a glass cylinder filled with glass beads, which have been moistened with a measured

FIG. 124.



Ammonia Cylinder.

quantity of standard sulphuric acid. A set of burettes, properly graduated, is provided.

"The maximum amount of ammonia allowed is 4 grains per 100 cubic feet of gas; and the testings shall be made so as to show the exact amount of ammonia in the gas.

"Two test-solutions are to be used, one consisting of dilute sulphuric acid of such strength that 25 measures (septems) will neutralise 1 grain of ammonia; the other a weak solution of ammonia, 100 measures of which contain 1 grain of ammonia.

"The correctness of the result to be obtained depends upon the fulfilment of two conditions :—

1. The preparation of test-solutions having the proper strength;
2. The accurate performance of the operation of testing.

"To prepare the test-solutions the following processes may be used by the gas examiner :—

"Measure a gallon of distilled water into a clean earthenware jar, or other suitable vessel. Add to this 94 septems of pure concentrated sulphuric acid, and mix thoroughly. Take exactly 50 septems of the liquid and precipitate it with barium chloride in the manner prescribed for the sulphur test. The weight of barium sulphate which 50 septems of the test-acid should yield is 13.8 grains. The weight obtained with the dilute acid prepared as above will be somewhat greater, unless the sulphuric acid used had a specific gravity below 1.84.

"Add now to the diluted acid a measured quantity of water, which is to be found by subtracting 13.8 from the weight of barium sulphate obtained in the experiment, and multiplying the difference by 726. The resulting number is the number of septems of water to be added.

"If these operations have been accurately performed, a second precipitation and weighing of the barium sulphate obtainable from 50 septems of the test-acid will give nearly the correct number of 13.8 grains. If the weight exceeds 13.9 grains, or falls below 13.7 grains, more water or sulphuric

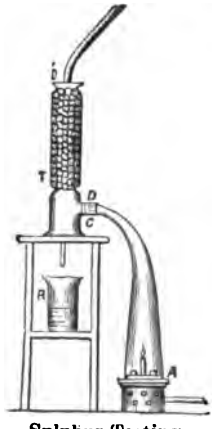
Digitized by Google

acid must be added, and fresh trials made, until the weight falls within these limits. The test-acid thus prepared should be transferred at once to stoppered bottles which have been well drained and are duly labelled.

"To prepare the standard solution of ammonia, measure out as before a gallon of distilled water, and mix with it 50 septems of strong solution of ammonia (sp. gr. 0.88). Try whether 100 septems of the test-alkali thus prepared will neutralize 25 of the test-acid, proceeding according to the directions given subsequently as to the mode of testing. If the acid is just neutralised by the last few drops, the test-alkali is of the required strength. But if not, small additional quantities of water, or of strong ammonia solution, must be added, and fresh trials made, until the proper strength has been attained. The bottles in which the solution is stored should be filled nearly full and well stoppered.

"The mode of testing is as follows:—Take 50 septems of the test-acid (which is greatly in excess of any quantity of ammonia likely to be found in the gas), and pour it into the glass cylinder, so as to well wet the whole interior surface, and also the glass beads. Connect one terminal tube of the cylinder with the gas supply, and the other with the meter, and make the gas pass at the rate of about half a cubic foot per hour. Any ammonia that is in the gas will be arrested by the sulphuric acid, and a portion of the acid, varying with the quantity of ammonia in the gas, will be neutralised thereby. At the end of each period of testing, wash out the glass cylinder and its contents with distilled water, and collect the washings in a glass vessel. Transfer one-half of this liquid to a separate glass vessel, and add a quantity of a neutral solution of hæmatoxylin or litmus just sufficient to colour the liquid. Then pour into the burette 100 septems of the test-alkali, and gradually drop this solution into the measured quantity of the washings collected, stirring constantly. As soon as the colour changes (indicating that the whole of the sulphuric acid has been neutralised), read off the quantity of liquid remaining in the burette. To find the number of grains of ammonia in 100 cubic feet of the gas, multiply by 2 the number of septems of test-alkali remaining in the burette, and move the decimal point one place to the left.

FIG. 125.



Sulphur Testing Apparatus.

"The remaining half of the liquid is to be preserved in a bottle duly labelled for a week.

"*Sulphur Compounds other than Sulphuretted Hydrogen.*—The gas which has been tested for sulphuretted hydrogen and ammonia shall pass next through a meter by means of which the rate of flow can be adjusted to half a cubic foot per hour, and which is provided with a self-acting movement for shutting off the gas when 10 cubic feet have passed.

"The testing shall be made in a room where no gas is burnt other than that which is being tested for sulphur and ammonia.

"The apparatus to be employed is represented above by Fig. 125, and is of the following description:—The gas is burnt in a small Bunsen burner with a steatite top, which is mounted on a short cylindrical stand, perforated with holes for the admission of air, and having on its upper surface a deep circular channel to receive the wide end of a glass trumpet-tube. On the top of the stand, between the narrow stem of the burner and the surrounding glass trumpet-tube, are to be placed pieces of commercial sesqui-carbonate of ammonia weighing in all about 2 ounces.

Digitized by Google

"The products both of the combustion of the gas and of the gradual volatilisation of the ammonia salt go upwards through the trumpet-tube into a vertical glass cylinder, packed with balls of glass, to break up the current and promote condensation. From the top of the cylinder there proceeds a long glass pipe or chimney, serving to effect some further condensation, as well as to regulate the draught and afford an exit for the uncondensable gases. In the bottom of the cylinder is fixed a small glass tube, through which the liquid (formed during the testing) drops into a beaker placed beneath.

"The following cautions are to be observed in selecting and setting up the apparatus:—

"See that the inlet-pipe fits gas-tight into the burner, and that the holes in the circular stand are clear. If the burner gives a luminous flame remove the top piece, and having hammered down gently the nozzle of soft metal, perforate it afresh, making as small a hole as will give passage to half a cubic foot of gas per hour at a convenient pressure.

"See that the tubulure of the condenser has an internal diameter of not less than $\frac{3}{4}$ inch, and that its outside is smooth and of the same size as the small end of the trumpet-tube.

"See that the short piece of india-rubber pipe fits tightly both to the trumpet-tube and to the tubulure of the condenser.

"The small tube at the bottom of the condenser should have its lower end contracted, so that when in use it may be closed by a drop of water.

"The india-rubber pipe at the lower end of the chimney-tube should fit into or over, and not simply rest upon, the mouth of the condenser, and the upper extremity of this tube may with advantage be given a downward curvature.

"At the end of each period of testing, the cylinder and trumpet-tube are to be well washed out with distilled water. Fresh pieces of sesqui-carbonate of ammonia are to be used each day.

"The gas examiner shall then proceed as follows:—

"The liquid in the beaker and the water used in washing out the apparatus shall be put into the same vessel, well mixed and measured. One-half of the liquid so obtained is to be set aside, and preserved for a week, properly labelled, in case it should be desirable to verify the correctness of the testing.

"The remaining half of the liquid is to be put into a flask or beaker covered with a large watch-glass, treated with hydrochloric acid sufficient in quantity to leave an excess of acid in the solution, and then raised to the boiling point. An excess of a solution of barium chloride is now to be added, and the boiling continued for five minutes. The vessel and its contents are to be allowed to stand till the barium sulphate settles at the bottom of the vessel, after which the clear liquid is to be as far as possible poured off through a paper filter. The remaining liquid and barium sulphate are then to be poured on to the filter, and the latter well washed with hot distilled water. (In order to ascertain whether every trace of barium chloride and ammonium chloride has been removed, a small quantity of the washings from the filter should be placed in a test-tube, and a drop of a solution of silver nitrate added; should the liquid, instead of remaining perfectly clear, become cloudy, the washing must be continued until on repeating the test no cloudiness is produced.) Dry the filter with its contents, and transfer it into a weighed platinum crucible. Heat the crucible over a lamp, increasing the temperature gradually, from the point at which the paper begins to char, up to bright redness.* When no black particles remain, allow the crucible

* An equally good and more expeditious method is to drop the filter with its contents, drained but not dried, into the red-hot crucible.

Digitized by Google

to cool; place it, when nearly cold, in a desiccator over strong sulphuric acid, and again weigh it when quite cold. The difference between the first and second weighings of the crucible will give the number of grains of barium sulphate. Multiply this number by 11 and divide by 4; the result is the number of grains of sulphur in 100 cubic feet of the gas. This number is to be corrected for variations of temperature and atmospheric pressure."

Mr. W. C. Young has shown that the quantity of sulphur in the liquid given by the Referees' apparatus may be much more quickly estimated by a volumetric process than by the usual gravimetric one. An aliquot portion of the liquor is run into a platinum crucible, a slight excess of acetic acid added to decompose all carbonate of ammonia, and a known excess of a standard solution of barium chloride added. The whole is then evaporated to dryness and ignited. The contents of the crucible are washed out into a porcelain basin, an *excess* of a solution of potassium chromate (free from chlorine) added, and the excess of barium chloride determined by a standard solution of silver nitrate. The quantity of barium chloride taken, minus the excess found by titrating with silver nitrate, gives the amount which has entered into combination with the ammonium sulphate.

The American chemists, Messrs. Sadler and Silliman, abandon the use of the carbonate of ammonia, and run in at the top of the condenser in the Referees' apparatus standard alkali from a burette. The volume of standard alkali run in during the combustion of a certain volume of gas is read off, and the excess of alkali in the liquid obtained determined; the loss of alkalinity corresponds with the amount of sulphur in the gas which has been oxidised during its combustion. By changing the receiver, without washing out the apparatus, this process may be made continuous.

Mr. T. Fairley runs in at the top of the Referees' apparatus a very dilute solution of hydrogen dioxide, and either estimates the sulphuric acid formed by standard alkali or precipitates it as barium sulphate in the usual way. This method may also be made continuous if the liquid in the receiver only be used for analysis.

Mr. Keates and, independently, Mr. Wanklyn have used iodine placed amongst the glass balls in the Referees' condenser, instead of carbonate of ammonia, around the burner. The well-known reaction takes place:—

$$SO_2 + I_2 + 2H_2O = H_2SO_4 + 2HI.$$

CHAPTER XVII.

Measurement and Storage of Gas.

On leaving the purifiers, and before entering the vessels employed for storing, the gas is usually passed through a station meter, or measuring apparatus, as a check on the total production. This for small and medium-sized works is made with a cast-iron cylindrical case, Fig. 126; while those of larger size have their cases rectangular, Fig. 127, and frequently present an imposing appearance, being of considerable dimensions. From 250,000 to 300,000 cubic feet per hour is the maximum size hitherto made, the case for which would be about 20 feet square. Several of such meters are required at the largest works. The construction of this apparatus is similar to that of the wet meter employed for measuring the gas supplied to each consumer, and which will be hereafter described. For small works, a timepiece and a mechanical contrivance called a tell-tale, are generally attached to the index of the meter, for the purpose of detecting any irregularities in the hourly

Digitized by Google

FIG. 126.

Small Works Meter.

FIG. 127.

Large Works Meter.

Digitized by Google

production of gas; but when the state of the index is taken and recorded hourly, as in most of the larger works, this automatic register is not required.

The production of gas and its consumption do not go hand-in-hand, the gas not being all consumed at the same time nor in the same quantity as it is evolved from the retorts.

This want of correspondence between the rate at which the gas is produced, and its consumption,—the former being, for economical reasons, almost uniform from hour to hour during the day and night, and from day to day (Sundays generally excepted), varying only with the seasons; whilst the latter fluctuates considerably during the hours both of daylight and darkness,

FIG. 128.

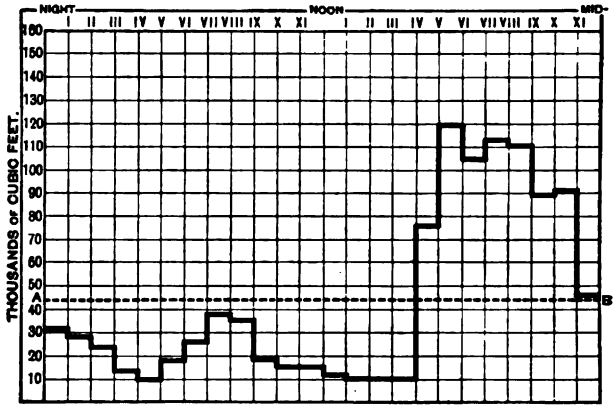


Diagram of Hourly Midwinter Output.

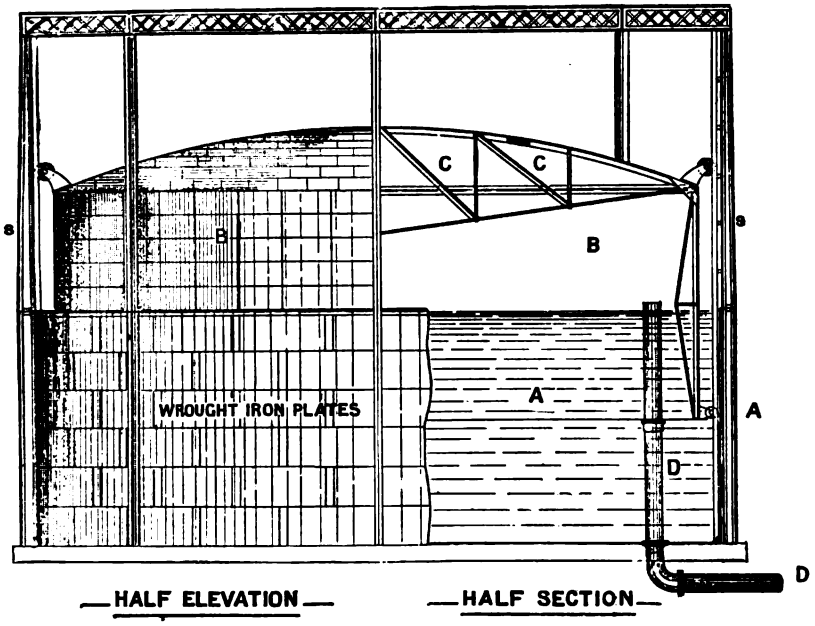
besides being influenced by the seasons,—is shown by the diagram (Fig. 128), which gives the average output from a large gas-works in a manufacturing town, during each of the twenty-four hours of a mid-winter's day, undisturbed by fogs or weather of exceptional severity. It conveys a tolerably accurate idea of the variations in the rate of consumption which have to be provided for, the straight line A B drawn across the diagram representing the production of an equal quantity of gas made at a uniform rate. It is thus seen that provision must be made for storing this, when it is in excess of the consumption, in order that such excess may be available for making up the deficiency when the consumption in its turn becomes the greater quantity. Beyond this, also, the fluctuations due to changes of the weather and other causes are so considerable, that it is always necessary to provide storage equal to at least three-fourths of the maximum daily production; whilst for manufacturing towns a much higher proportion—viz., $\frac{5}{4}$ths—is generally required.

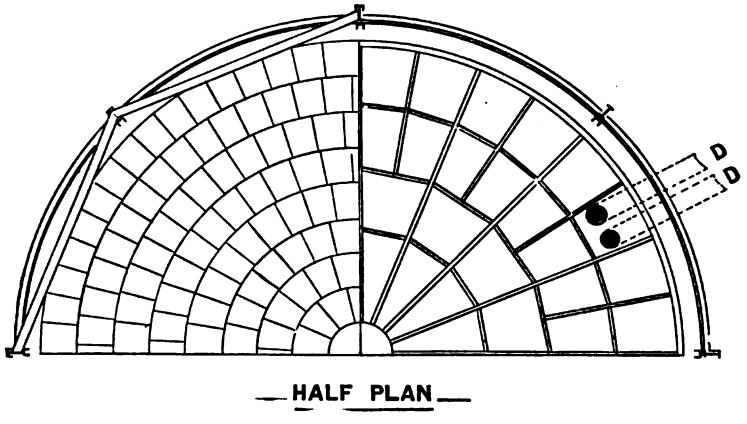
Large inverted cylindrical vessels, which are open at the bottom and dip into water, are employed for storing the gas; these not only act as repositories for the gas, but the weight of the vessels supplies the force by which it is sent onward through the mains to the consumers. The gasholder thus consists of two parts, the tank A A A (Fig. 129), which is filled with water and prevents the gas from escaping, while presenting a resisting surface to the gas, either incoming or outgoing, and the holder itself B B, which is raised or lowered according to the quantity of gas to be stored.

Digitized by Google

The first tanks were made of cast-iron, or timber, brewers' vats being occasionally resorted to; but these speedily gave way to brick and stone, whilst concrete is now not unfrequently the only material employed. Cast or wrought iron, A, Fig 129, is, however, still occasionally used, when the soil

FIG. 129.





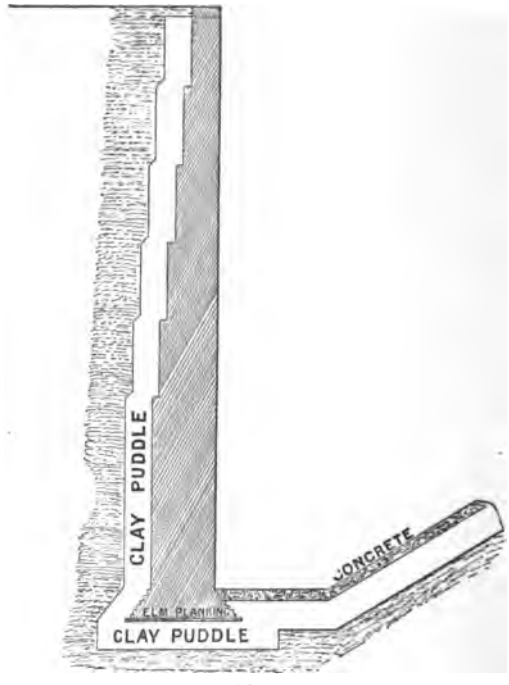
asholder, Plan Elevation, and Section.

is of such a nature as to prohibit any considerable depth of excavation. With the necessity for larger gasholders, increasing attention has had to be bestowed on tank construction, which has now become a highly important branch of gas engineering. Tanks made of brick, stone or concrete, are usually sunk level with the ground, or have their copings only a few feet above the surface, in which case the walls are protected by a suitable mound of earth. As they have frequently to be of considerable depth, the deepest at

Digitized by Google

the present time being 55 feet from the coping level, the greatest care is necessary in selecting the site. Trial holes are first sunk for the purpose of ascertaining the nature of the subsoil which, at the required depth, ought to give promise of a suitable foundation, and of being without difficulty kept free from water by pumping during the progress of the work. Of all soils, good stiff clay is perhaps the best for tank building, because it is of itself impermeable to water, but excellent tanks are built upon a foundation of chalk or sand rock, and even upon drift sand. When clay is to be had in abundance, a perfect basin of clay puddle is formed in the excavation, within which the tank walls of brick or concrete are built, as shown in Figs. 130, 131, in which the

FIG. 130



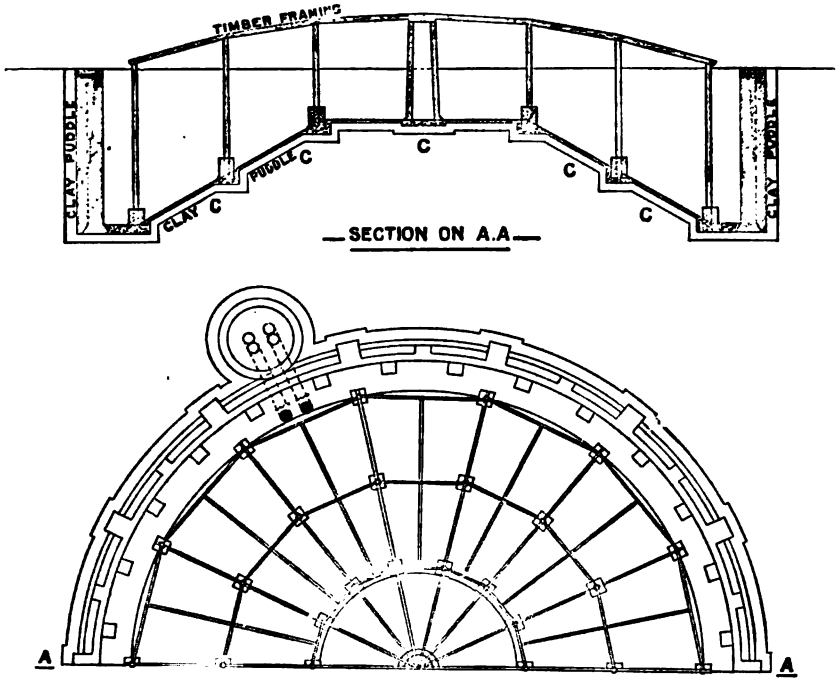
Gasholder Tank.

wall is of brickwork; but when this is comparatively scarce, the tank is made water-tight by an interior coating of Portland cement rendering. A notable example of this method of construction is at the Old Kent Road Works, where a tank 220 feet in diameter and 55 feet deep, has been built by Mr. George Livesey, entirely of concrete made from retort-house débris mixed with ballast procured from the excavation, and lined throughout with Portland cement rendering; whilst at the East Greenwich works of the South Metropolitan Gas Co. a tank more than 300 feet in diameter, the largest yet built, is of similar construction. At Birmingham, also, two tanks, constructed entirely of brickwork by Mr. Charles Hunt, each 240 feet in diameter and 51 feet deep, are made water-tight in the same way. It is customary to take out the whole of the soil included within the tank walls, with the exception of a portion sloping up towards the centre, and called the "cone" C C C C, Fig. 131, the dimensions of which vary according to the nature of the ground. Occasionally, the "annular" method of construction

Digitized by Google

has been followed; that is to say, an inner wall is built within a few feet of, and parallel to, the outer walls; the space between them being filled with water, in which the gasholder works; but this, as regards most soils, is open to serious objection from its costliness, because where the earth is loose the inner wall must be built of sufficient strength to resist the pressure behind it, for which, unlike the outer wall, it is unassisted by its curvature. Except, therefore, where the excavation has to be carried through rock or sandstone, or in some cases where from the nature of the soil it is deemed

FIG. 131.



Gasholder Tank.

advisable to construct the tank of cast or wrought iron, this method is seldom followed.

The pipes which convey the gas to and from the gasholder, D D, Fig. 129 (p. 151), are usually carried down the outside of the tank in what is called a "dry" well, underneath the footings of the wall, and up through the water to a few inches above the level of the latter. On the Continent, however, it is not unusual to employ articulated pipes, connected to the crown of the gasholder, and thus adapted to its rise and fall.

During the first few years after the introduction of gas-lighting, rectangular gasholders were employed, of a capacity not usually exceeding 500 cubic feet. These were made of great strength to resist external pressure by framing the interior with timber and iron, a practice which existed to some extent for a considerable period after the introduction of the cylindrical form in 1815. Nor were the properties of coal gas better understood in those early days than the influence of atmospheric pressure,

Digitized by Google

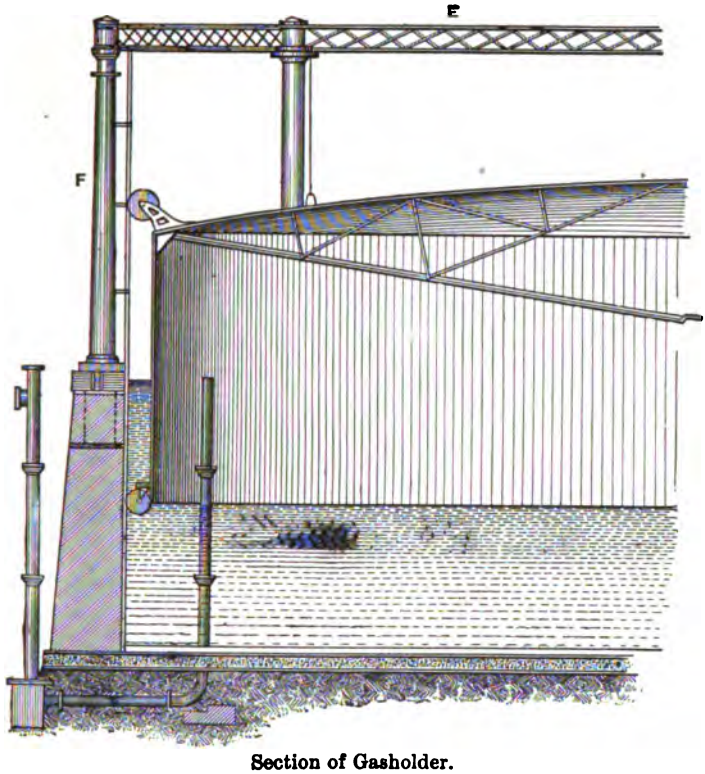
for the most extraordinary precautions were taken to minimise the possible effect of an explosion by enclosing all gasholders within substantial buildings, traces of which practice were, until a comparatively recent period, still extant in one or two of the oldest gas-works. To John Malam is largely due the credit of dispensing with the heavy internal framing, and also of counterbalancing the holder with weights and chains for relieving the pressure; an arrangement of considerable importance in those early days in its effect on the economy of manufacture. In 1819, Peckston in his "Theory and Practice of Gas Lighting," says: "Experience has now taught the manufacturer that he cannot construct the gasholder too light: instead of the wooden frame or weighty iron stays, that vessel consists now of nothing save the plates rivetted together, and an angle iron at the bottom, and another angle iron inside at the top for keeping it in form, together with six or eight small rods which project from the eyebolts, by which the gasholder is suspended. Under this arrangement the gasholder is light, and consequently costs much less in the first instance; it requires less balance weights, lighter friction wheels, and, in short, under all its bearings, it is attended with benefits." This description, although somewhat in advance of the general practice at that time, was not long in acquiring recognition as defining the true method of construction, which has since received continuous development, with highly important results as affecting the economy of the apparatus. Heavy internal framing, although here and there adhered to, or occasionally revived, has long since, as an accepted rule of construction, been abandoned.

When gas was first introduced into the metropolis, a recommendation was made to Government by a Commission of the Royal Society, that no company should be allowed to construct gasholders exceeding 6000 cubic feet capacity each, and these were to be confined in very strong buildings. At the present time, the largest gasholders in use have a capacity varying from 5,250,000 to upwards of 12,000,000 cubic feet each. This great development has been attained by an extension of the system known as "telescoping," by which the capacity for storage of gas is increased two, three, and even sixfold, without any additional tank space. What is called a single-lift holder is a cylindrical vessel usually varying in depth from one-fourth to one-fifth the diameter, and strengthened by a stiff curb of angle or channel iron at top and bottom, where it is also provided with guide rollers placed equidistant round the circumference. Corresponding with these are the roller paths, usually formed of channel iron, along which the guide rollers travel as the gasholder moves up and down; these are secured to the tank wall, and continued upwards to a height corresponding with that of the gasholder when filled. Rising from the tank wall is a wrought or cast iron framing, E F, Fig. 132, which surrounds the gasholder, and to which is secured the upper portion of each roller path. In most cases, this external framing is formed of a series of cast-iron columns bolted down to the tank wall, and tied to each other at the top with wrought-iron girders. Each column is provided at intervals with cast-iron brackets to which the roller path is secured. When cast-iron weights are employed as a counterpoise to a part of the weight of the holder, these are suspended by means of chains passing over guide wheels placed on the top of each column, and secured at the other extremity to the top curb of the holder. This practice is, however, not now resorted to. With the introduction of exhausters, by which the retorts are entirely relieved from the pressure due to the resistance of the apparatus, the necessity for counterbalancing has ceased; moreover, a lighter method of construction has become more general.

It was with the object of storing a larger quantity of gas in the same superficial space, that Tait proposed the telescopic system already referred

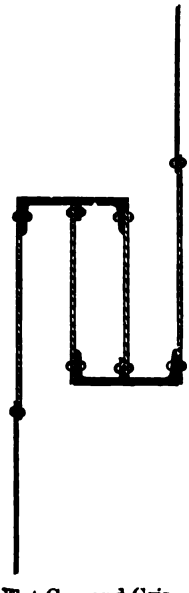
Digitized by Google

FIG. 132.



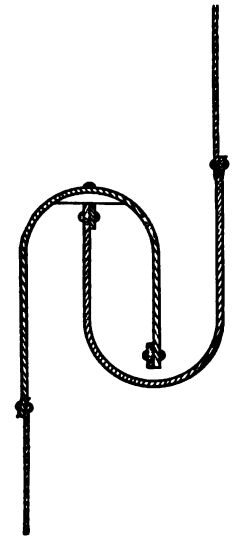
Section of Gasholder.

FIG. 133.



Flat Cup and Grip.

FIG. 134.



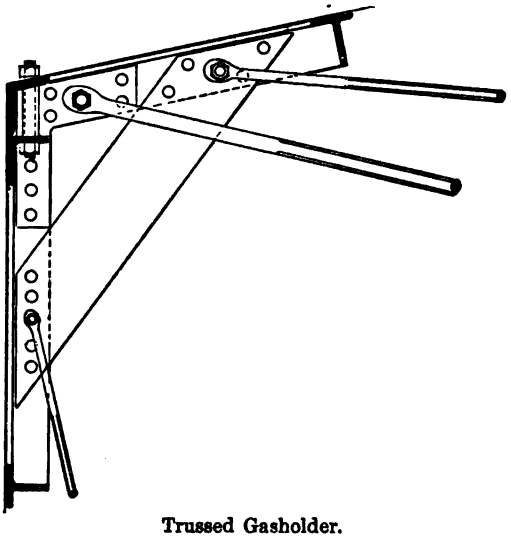
Piggott's Cup and Grip.

Digitized by Google

to, and which consists of several cylinders placed one within the other, like the separate tubes of a telescope, the innermost of which only is closed at the top, and all are contained in a single water-tank.

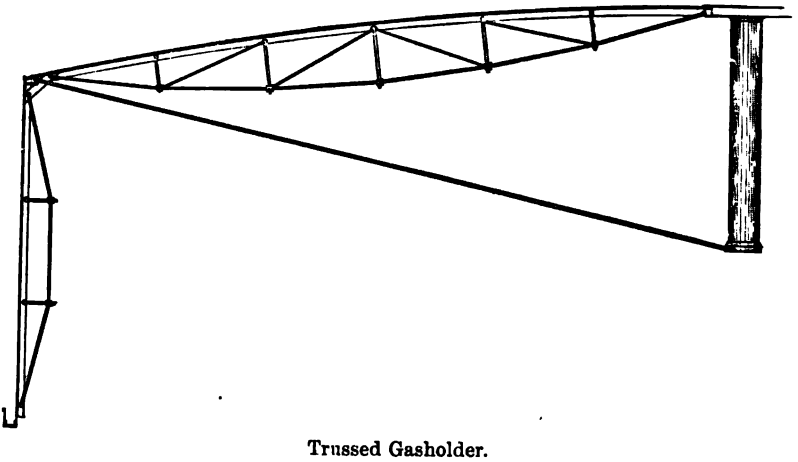
The upper edge of each of the lower cylinders has a broad flange turning downwards on the inside and called a "grip," whilst the lower edge of the inner cylinder is turned upward and outward, forming what is termed a "cup." When the gas enters, the inner vessel first ascends, and having arrived at its greatest height, raises the next, by means of its "cup" catching the "grip" of the second, while the "cup," having been immersed in water, remains full, forming a water lute, and preventing the escape of gas. In place of the flat cup and grip, formed of channel iron, with side plates rivetted thereto, as shown in Fig. 133 (p. 155), what is known as Piggott's cup and grip are frequently employed, the top plates of the inner and the bottom plates of the outer lifts being bent round to the required shape (Fig. 134, p. 155).

FIG. 135.



Trussed Gasholder.

FIG. 136.



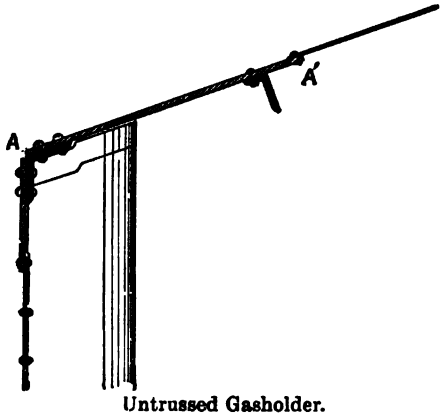
Trussed Gasholder.

According to the construction of the crown or roof, gasholders may be described as of two classes: the trussed, in which the crown sheets are supported by a trussed frame rising and falling with the gasholder; and the untrussed, in which a framing, sometimes made of iron, but more generally of timber, forming a part of the tank construction, sustains the weight of the crown when the holder is out of action. Figs. 129 and 132 (pp. 151, 155)

Digitized by Google

show the former in which the trusses serve also the purpose of keeping the top curb in shape, Figs. 135 and 136 showing the construction of the curb and attachments of truss rods. In most cases a support of some kind is necessary; and it is contended that for gasholders of moderate dimensions trussing is to be preferred. For large holders, however, the advantages appear to be clearly on the side of the timber framing, shown in Fig. 131 (p. 153) in elevation and plan, not only in point of economy, because the strength and consequently the weight of the trussing have to be increased as the square of the diameter of the holder, but also as reducing the top weight, and so improving the stability of the vessel. Hence all the largest gasholders are of the untrussed class, in which, however, the top crest is materially strengthened, usually by the addition of an angle iron ring A′, Fig. 137, and by increasing the thickness of the first rows of the side and crown sheets; occasionally, also, these, together with the two angles, A A′, are made of steel. To reduce the strain on the curb, a greater rise is generally given to the crown of an untrussed gasholder than is considered necessary when trussing is resorted to. Cripps ("Transactions of the Gas Institute" for 1882) shows that the strain on the top sheeting and also on the top curb varies directly as the radius of the sphere of which the top is a segment, and the formula for determining the radius is stated as follows:

FIG. 137.



Untrussed Gasholder.

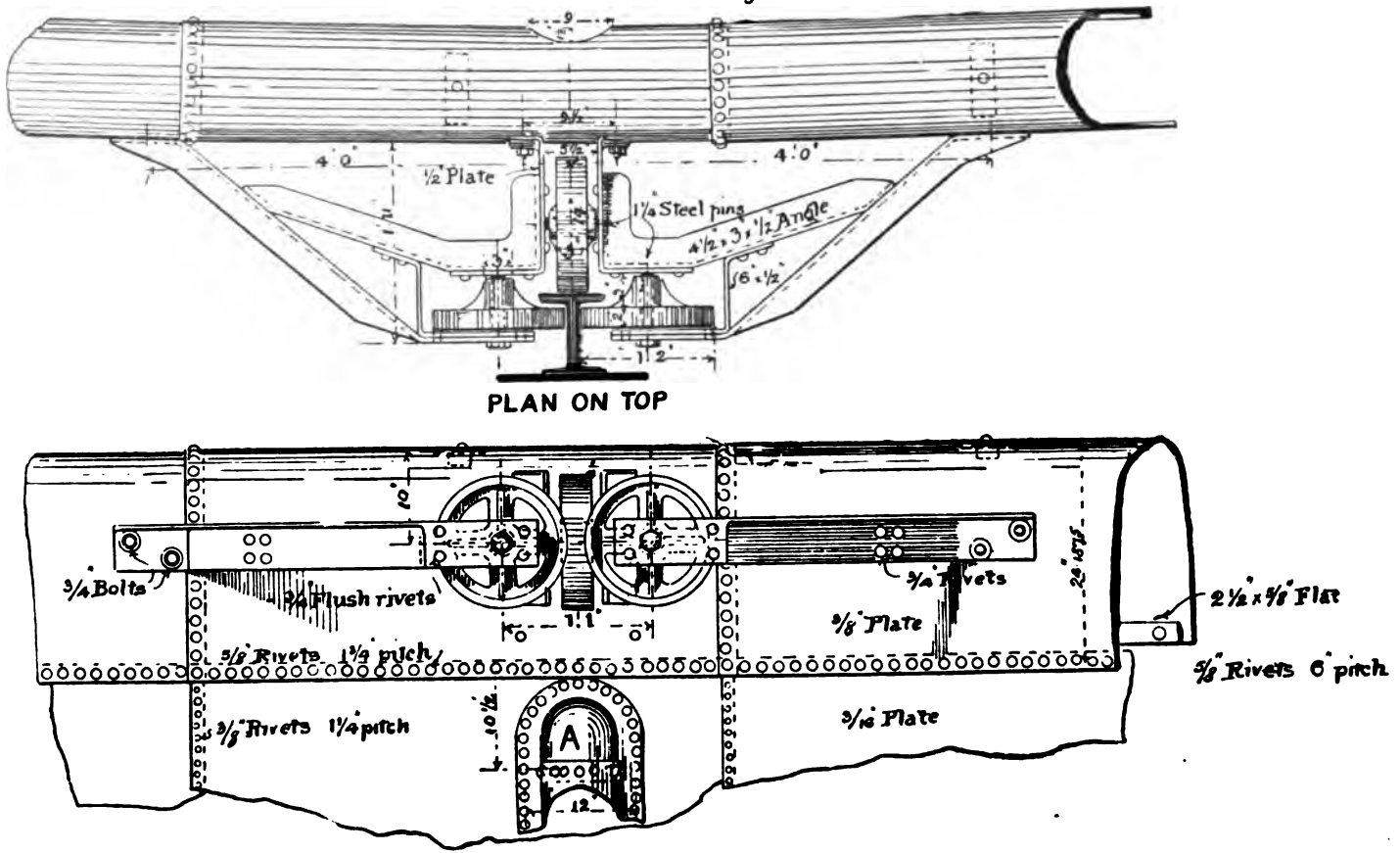
A = half the diameter of holder in feet.
B = rise of crown in feet.
$\frac{A^2 + B^2}{2B}$ = radius.

Taking as an example a holder 60 feet in diameter, it is shown that with a rise of 1 foot the strain as compared with a rise of 6 feet is as 450.5 to 78. Large gasholders recently constructed have a rise at the centre of the crown of from 20 to 25 feet.

The wrought iron or steel sheets forming the body of a gasholder have a thickness not exceeding $\frac{1}{8}$th of an inch, but the crown sheets are usually somewhat thicker; and stronger sheets are also used next to the cups, grips, and curbs, which last may be formed of plates varying in thickness from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. For strengthening the side sheets a number of trusses, Figs. 129 and 136, may be fixed at equal distances around the interior. When, however, the lifts are of considerable height, the side sheets of the inner lift are strengthened by vertical trough-shaped iron stiffeners, rivetted at equal distances around the interior, one of which is shown at the side of Fig. 137. The intermediate and outer lifts are strengthened on the inside by channel irons, which serve also as guides for the bottom rollers of the inner lifts, and frequently on the outside as well by semicircular iron stiffeners, Fig 138, A. Radial guide rollers have usually been employed in this country, although in France tangential rollers have long been preferred. Mr. Livesey in the large holder at the Old Kent Road Works employed a combination of radial and tangential rollers, Fig. 138, p. 158, and this arrange-

Digitized by Google

FIG. 38.



Livesey's Radial and Tangential Rollers.

Digitized by Google

ment, which possesses many advantages, has been generally followed in the construction of large holders. In the case of the 12,200,000 cubic feet gasholder at East Greenwich, some of the rollers are placed at an intermediate angle, being neither radial nor tangential, but combining the advantages of both. A single-lift gasholder is generally of sufficient weight to give a pressure of 3 or 4 inches head of water, and each outer lift, in the case of a telescopic gasholder, about 2 inches additional pressure. The pressure capable of being exerted by a gasholder may be calculated by the following formula, its weight being known:

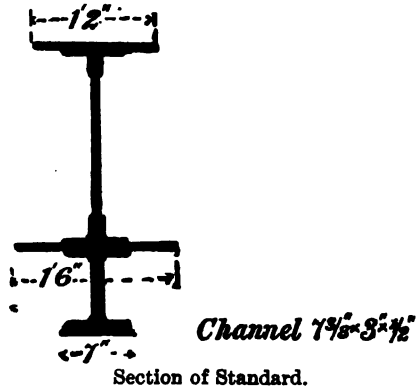
W = the weight of gasholder in lbs.;
a = area of gasholder in feet;
P = pressure in inches, head of water;

$$\text{then } P = \frac{W}{a \times 5.21};$$

5.21 lbs. being the weight of $\frac{1}{12}$th of a cubic foot of water, and the weight in lbs. of any gasholder may be ascertained, if the pressure be known, by the formula $W = P \times a \times 5.21$.

It has been stated that the guide framing, within which the gasholder moves when rising and falling, is generally formed of cast-iron columns secured to each other at the top by a continuous circle of wrought or cast iron girders. Wrought iron is, however, often employed, and the guide framing in the case of the large holders already referred to, and which when fully inflated rise to a height of from 130 to 190 feet, consists almost wholly of this material; the reason for its adoption being its superior lightness and strength. Its suitability in this respect has, indeed, contributed very materially to the great development which has taken place in the size of these structures during recent years. The cost both for labour and material of a guide framing formed with cast-iron columns necessarily increases in greater proportion than its height, because of the extra weight of metal needed to sustain the additional height, and of the greater risks attending erection. So long, therefore, as cast-iron continued to be chiefly depended upon for this purpose, because of the security believed to be afforded by its superior rigidity, no great increase of height could be looked for, and there was some ground for the opinion which to a great extent prevailed, that the limit of size had been reached with gasholders having a capacity of 2 or 2½ million cubic feet. Attempts were made to give an appearance of lightness to the construction by substituting for the columns cast-iron girders like cantilevers placed on end. In 1878 Mr. Corbet Woodall demonstrated the practicability of a further step in advance by constructing a holder with a capacity of upwards of 3,000,000 cubic feet, the guide framing of which is of this description, but partly of wrought iron. But the very great practical and economical advance which gas engineering has achieved in this direction is mainly due to the originality and enterprise of Mr. George Livesey, who conceived the idea of combining in the guide framing the extreme of lightness with a height, and consequent capacity

FIG. 139.

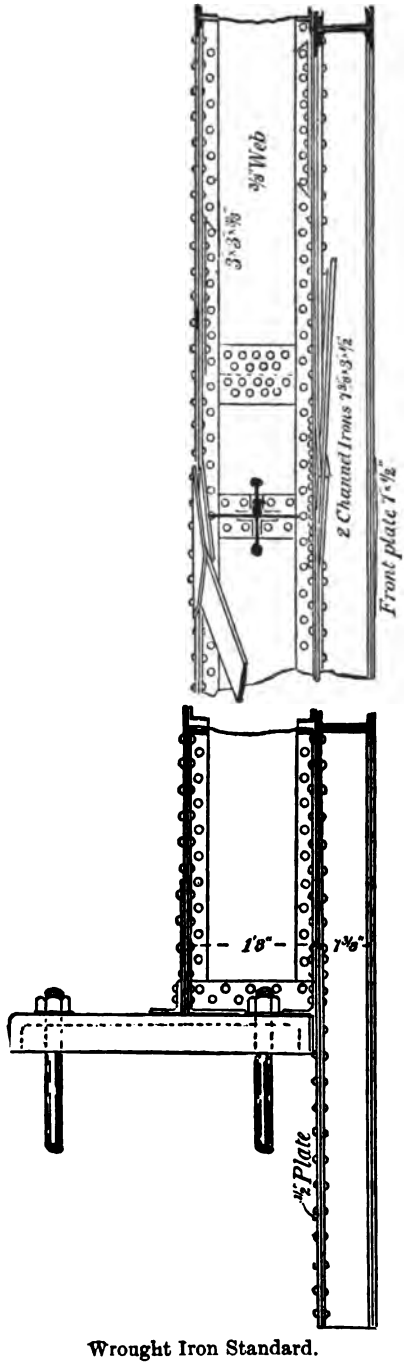


Section of Standard.

Digitized by Google

of holder greatly exceeding any that had previously been considered practicable. The success of his designs overthrew the old notion of the necessity for a heavy guide framing, and initiated a new train of thought, the first outcome of which was a more intelligent appreciation of the strains to which the gasholder and its guide framing are subject when in actual use. This somewhat difficult problem had been earlier treated of by M. Arson, Engineer to the Paris Gas Company, and has now been ably worked out by Mr. F. S. Cripps, whose work, entitled "The Guide-framing of Gasholders, and other Papers chiefly relating to Strains in Structures connected with Gas Works," forms a text-book upon the matter to which it relates.

FIG 140.



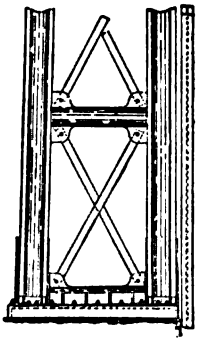
Wrought Iron Standard.

In the gasholders designed by Mr. George Livesey a series of wrought-iron standards, Figs. 139 (p. 159) and 140, in construction similar to a girder placed on end, takes the place of the cast iron columns. These are fastened together at intervals throughout their height by cross-shaped wrought-iron studs or girders, and the strains due to wind pressure acting on the surface of the holder are taken by flat wrought-iron ties which, extending from top to bottom, are rivetted alternately to the back and front flange of each standard, uniting the whole structure firmly together—forming, in fact, a braced cylinder within which the gasholder moves. Much the same idea has been carried out by Mr. Charles Hunt, in his design for the Birmingham holders, only in this case the standards, shown in Figs. 141 and 142, instead of being formed of a single member, are made to consist of two—namely, a back and front leg, placed about 4 feet apart at the bottom, and meeting together at the top, where they are united by a wrought-iron plate forming a complete circle round the holder. Each leg is a cylinder 12 inches diameter, made with pile channel iron rivetted together with external flanges. Perfect rigidity of the standard is secured by cast-iron struts and

Digitized by Google

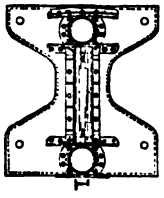
wrought-iron diagonal bracing, as shown in the illustration. Continuous flat wrought-iron ties are rivetted by means of wing plates to the back

FIG. 141.



Elevation.

FIG. 142.



Section.

Wrought Iron Standard.

of the outer leg of the standard, the whole forming an extremely strong guide framing.

Cutler's guide framing, of which Figs. 143 and 144 are illustrations,

FIG. 143.

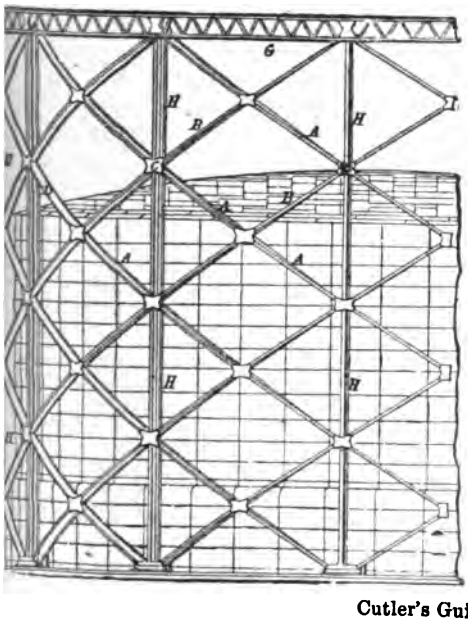
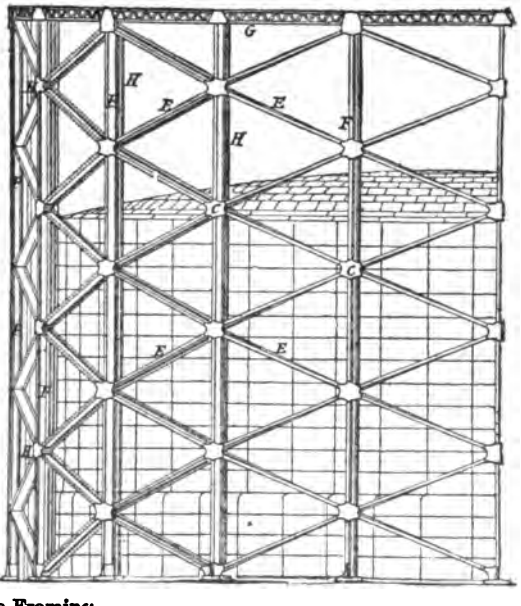


FIG. 144.



Cutler's Guide Framing.

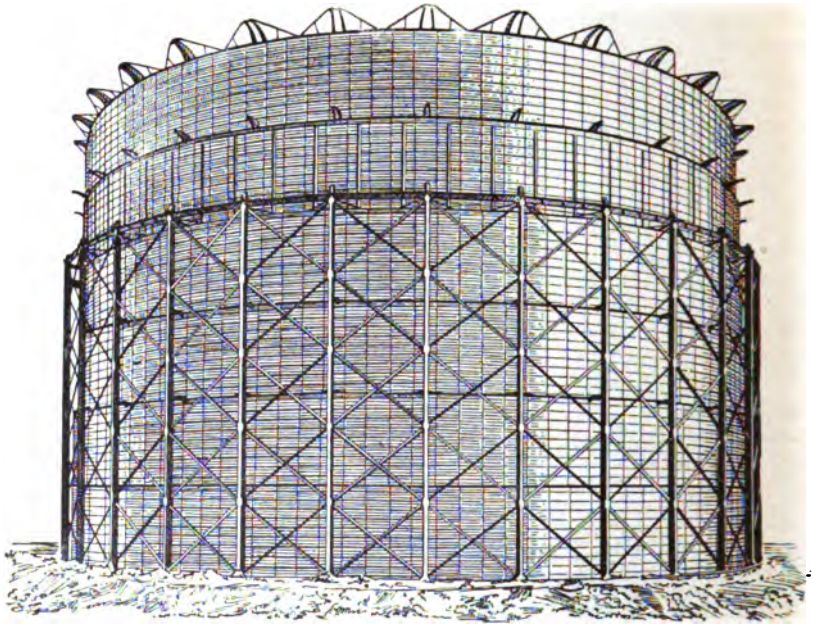
consists of a series of H-irons, fixed diagonally so as to form a complete cylinder of combined struts and ties. This forms an effective framing, at a reasonable cost.

Digitized by Google

Other forms of gasholders, one having a central column, to take the place of an outer guide framing, have been proposed by Barker, Wyatt, and others.

In 1881, Mr. George Livesey suggested the possibility of erecting gasholders with a guide framing considerably short of the height to which the gasholder rises; and a few years later he followed up this suggestion by adding a third lift to a holder at the Rotherhithe Gas Works, without correspondingly raising the guide framing. Other gasholders, similarly

FIG. 145.



Gasholder at Rotherhithe.

constructed, have followed; the latest being one of 12,200,000 cubic feet capacity, and consequently the largest in the world. This has six lifts, the two inner of which rise above the framing, as shown in Fig. 145.

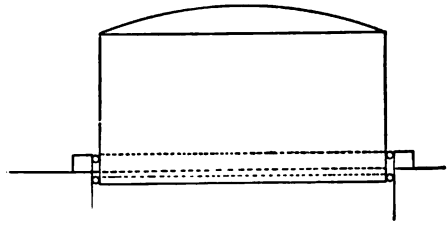
In 1887, Mr. W. H. Y. Webber, in a paper read by him at the annual meeting of the Gas Institute, advocated the construction of gasholders without any guide framing; but, in place of it, a circle of short piers carrying a continuation of the tank guides; with two points of bearing for the holder supplied by ordinary bottom rollers secured to the bottom curb and a second tier about six feet above them, Fig. 146.

Following up this idea, Mr. W. Gadd, in the same year, patented, in conjunction with Mr. Mason, an arrangement of spiral tank guides as a substitute for elevated guide framing. This is shown in Fig. 147, and is thus described by Mr. W. Newbigging: "The invention consists in placing the channel or other guides within the tank at an angle, like the thread of a screw, instead of in the vertical plane, as has hitherto been the invariable practice. The guide rollers attached to the bottom curb of the holder are ranged either radially or tangentially with the sides of the vessel; and as they work in the channel or rail guides provided for them, a helical or screw-

Digitized by Google

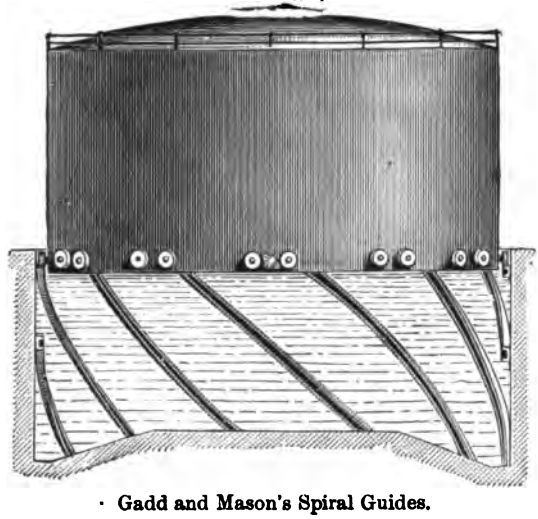
like motion is communicated to the floating vessel as it rises and descends in the tank. . . . The guides attached to the tank sides may be placed at any angle from 45° upwards. . . . The effect of thus arranging them is obvious. So long as the rollers are free to move within the guides, it is impossible that the holder can tilt so as to get out of the vertical; the tendency of wind or other pressure exerted against the sides or on the roof of the vessel being to produce what may be described (imperfectly, however) as a locking action, which will sustain the holder in the upright position, however great the strain, within the resisting strength of the rollers and their carriages. Whilst this locking or gripping action gives rigidity to the vessel, enabling it to resist the overturning force, the rollers are perfectly free to rise and descend within the guides."

FIG. 146.



Webber's Gasholder

FIG. 147.



Gadd and Mason's Spiral Guides.

Some forty to fifty gasholders have already been constructed on this principle, the largest, a three-lift holder, being upwards of 130 feet in diameter and 90 feet in height.

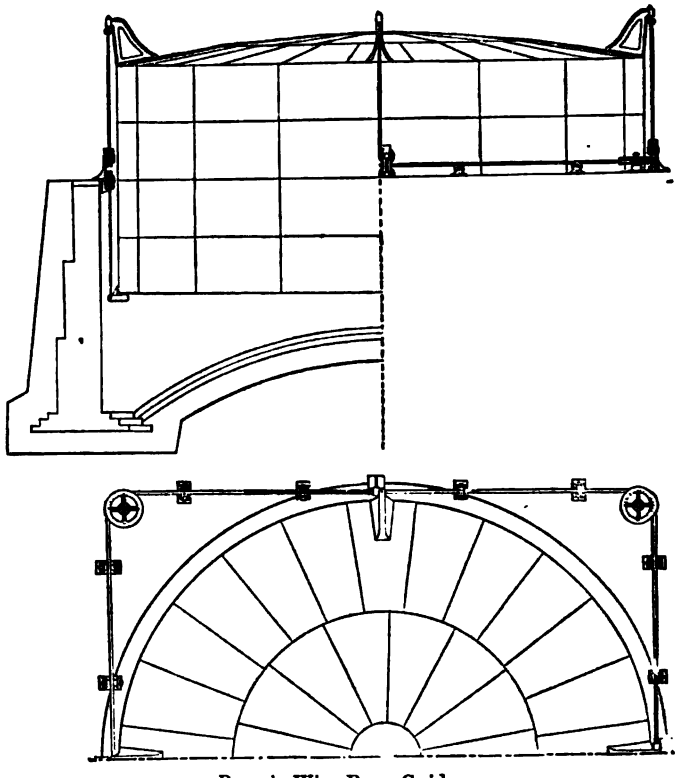
The specification of a further patent taken out by Messrs. Gadd and Mason, dated December 12, 1888, comprises several other methods for supporting gasholders in their working position without upper guide framing. "It is proposed to fix round the face of the tank a series of vertical guides, constructed in the form of racks or mechanical equivalents therefor—such as vertical screw-shafts of coarse or quick thread, or vertical endless chains or bands passing over and between pulleys or wheels at or near the top and the bottom of the tank or holder, as the case may be. At corresponding intervals round the lower curb or ring of the holder, there are mounted on suitable shafts or studs, pinion, mitre, or other toothed wheels or mechanical equivalents therefor—such as notched wheels, or in some cases plain wheels or pulleys, which gear into or with the racks or equivalents aforesaid. These wheels are, by preference, all likewise geared together in such manner that, when one is caused to turn, the whole will turn therewith and to the same extent. By these means, if the holder carrying or connected with these geared-up wheels moves upwards or downwards, it will be sustained in the same relative position at all heights. The like result is also obtained by fixing the vertical racks or equivalents to the outer face of the holder;

Digitized by Google

and the pinion, mitre, or other wheels, round the top of the tank. In like manner, the method may be extended to telescopic holders. The wheels which take into the guides may be geared together either by shafts, intermediate between, and turning in suitable journals; by means of intermediate wheels in train; or by a plain chain or rope, or link-chain gearing; and, instead of the whole of the wheels being geared together, portions only may be geared as a modification.

"Other variations in detail may be made without departing from the

FIG. 148.



Pease's Wire Rope Guides.

peculiar character of the invention, which consists in connecting, by means of torsional or terminal gearing, a number of points round the bottom curb of a gasholder in such a manner that, when one point thereof tends to rise or fall, the same tendency is transmitted through such gearing round the circle to every other point."

The invention of Mr. E. Lloyd Pease, patented in 1888, for dispensing with the guide framing, and substituting for it a system of wire rope guiding is shown in Fig. 148. It is thus described in the *Journal of Gas-Lighting*: "The system may be regarded as two developments, the first involving a combination of a moving ring girder and wire rope attachments, the second dispensing with the girder and making use of ropes only. The former is perhaps easier described and understood. We have to imagine then a single-lift gasholder, grounded in its tank and ready for raising. It has no guide columns; only tank guides and rollers. It has on the top curb

Digitized by Google

three or more goose-necks, however, very like those in ordinary use, but without the rollers, which, of course, would be useless in the absence of anything to roll against. In place of the rollers every goose-neck carries at its outer extremity a wire rope as long as the holder is high, secured by a vertical screw-rod coupling, from which it hangs perpendicularly downwards. On the ground and round the tank lies on stout roller bearings, anchored to the ground, a circular girder of H-iron, of, say, the same strength as would be required for a column guide. By means of the rollers on which it lies, and which are in pairs, one over another, holding it securely between them, this girder can be made to move in either direction concentrically round the holder. The wire ropes already mentioned as hanging from the top goose-necks, are brought down vertically to the top of the girder, and after passing underneath a pulley, are made fast to the top surface of the girder, lying along it, say, from left to right. From the underside of the girder, other similar ropes pass from right to left, also changing direction by means of pulleys, down to the bottom curb of the holder, where their other end is made fast. . . . In the position supposed to be occupied by the holder—resting on the stones in the bottom of the tank—the upper guide ropes are lying with most of their length aligned with the movable ring girder, while the under guide ropes are fully paid out and hanging at their vertical length in the tank. If now the holder is raised by gas, as it rises it takes up its top guide ropes, which, being fast to the girder, pull the latter round to the same extent horizontally and circularly as the holder goes up vertically. At the same time, the lower guide ropes are drawn out of the tank and go round with the girder. So the movement goes on, until (when the holder is full) all the upper guide ropes are fully paid out, and the lower ones are laid along the girder. As the holder falls, the reverse process takes place. The bottom guide ropes now pull the girder the contrary way, and it takes up the slackened top guide ropes as it revolves. No rope can go faster than another, and so the verticality of the holder is assured at all heights. The screw attachments permit of adjusting the ropes so that they may all be equally strained; and as their rate of motion is slow, their wear is inappreciable. It will be seen that a holder thus tied from the top and bottom is even more securely held upright than by the ordinary method of rollers and guides, because the controlling strain is always operating, and does not depend, as in the usual method, on the weight of the holder happening to rest now on one side, now on another, as it rises and falls.

"The second or modified development of the system consists in substituting a stout endless wire rope, held in anchored horizontal grooved guide pulleys, for the solid guide. The operation is precisely the same. As the holder rises, the top guide ropes which are fastened to it by their lower ends pull the horizontal endless ropes round in one direction; and when it falls the bottom guide ropes, which are similarly fastened to it, pull it round in the opposite direction. The advantages of substituting a wire rope for the heavy solid guides are obvious. It is cheaper; saves weight; is much easier to fix; and as it runs straight between its guide pulleys it takes the strain better. If necessary, one or more of the guide pulleys may be made traversing on its carriage, to allow for taking up slack caused by wear."

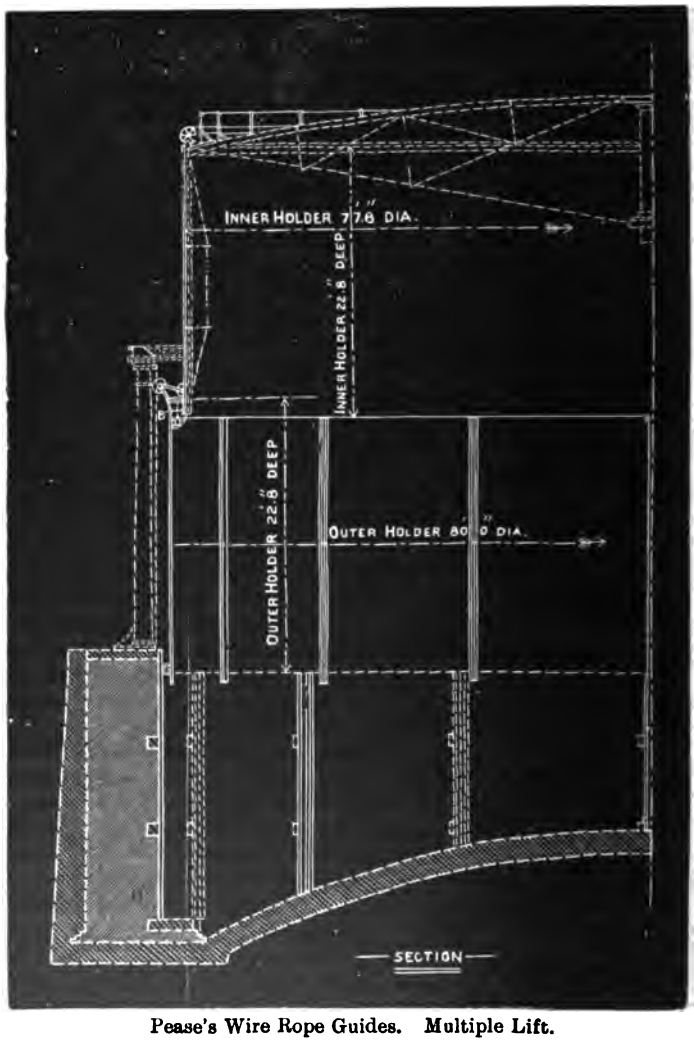
It is further stated that the application of the system to multiple-lift holders is simple in the extreme; and Mr. Pease has made a modification of it to meet the case of a holder which is enlarged by the addition of a new inner lift. In this case, the horizontal anchored rope, which sustains the whole, is placed upon the crown of the holder and goes up and down with it. By this device the existing columns and guides of the lower lifts are not interfered with. Figs. 149 and 150 show sectional elevation and plan of a gas-holder at Haslingden Union Gas Works, 80 feet diameter and 22 feet deep,

Digitized by Google

which has been enlarged by the addition of a new inner lift, with Pease's wire rope guiding.

Mr. J. B. Terrace proposes (*Journal of Gas-Lighting*, 1889, liii. 62) to dispense with the upper guide framing by surrounding the holder with a tier of spur wheels keyed upon spindles long enough to reach the distance at which guide columns are ordinarily placed round the tank. The journals

FIG. 149.



Pease's Wire Rope Guides. Multiple Lift.

carrying the spindles are, according to his arrangement, borne upon cantilevers or brackets securely anchored in the tank wall. Racks to gear with the spur wheels are attached to the holder; and the consequence of this disposition is that the gasholder cannot rise or fall unequally. The line of gearing is fixed about six feet from the ground, requiring the racks to be carried, say, 6 ft. 6 in. above the top curb; but they need not be taken down nearer than 5 ft. 6 in. from the bottom curb. This arrangement appears to be

Digitized by Google

anticipated by the patent of Messrs. Gadd and Mason, previously described. It is thus seen that the tendency of modern engineering is in the direction of dispensing, either wholly or in part, with the use of the upper guide

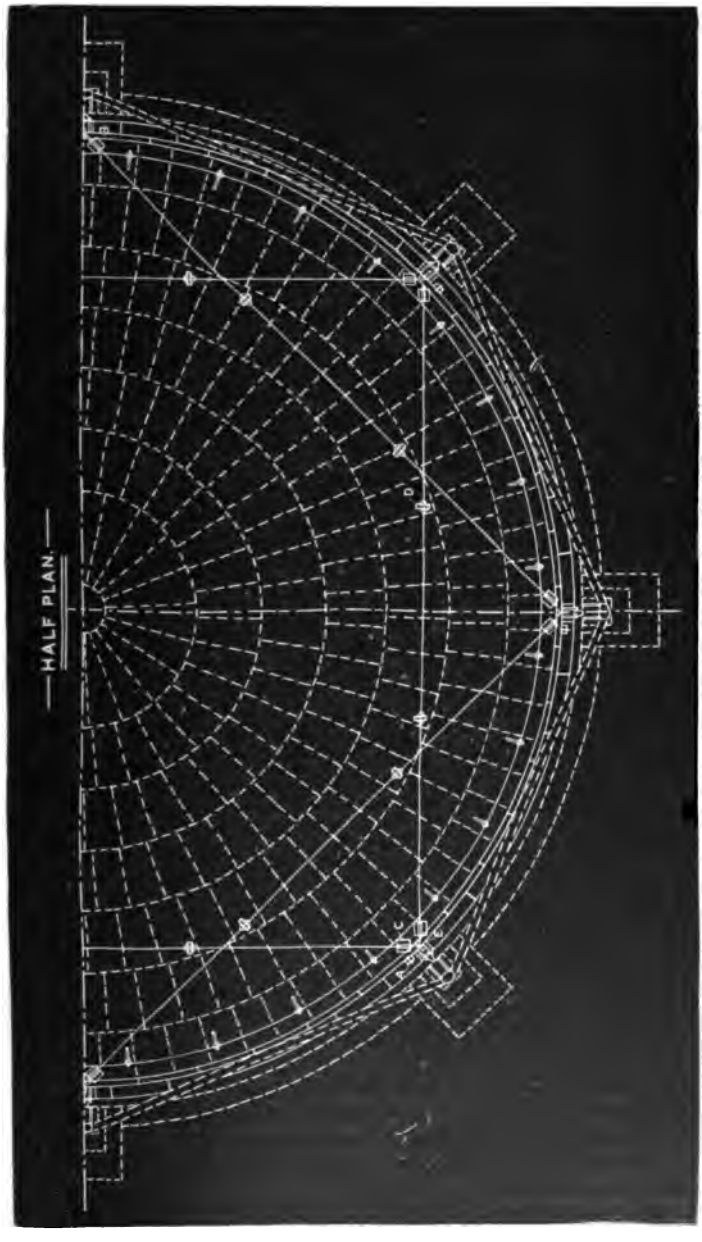


FIG. 150. —HALF PLAN.— Pease's Wire Rope Guides. Multiple Lift.

framing of gasholders. In the interests of economy, this is by no means to be regretted, although it perhaps affords less scope for the skill of the designer. At the same time it has yet to be shown that any of the proposed substitutes for guide framing are applicable to gasholders of large dimensions.

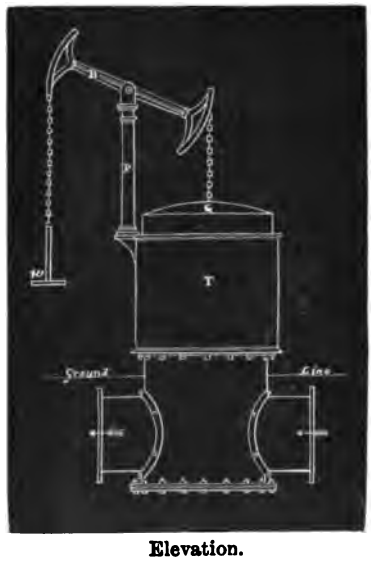
Digitized by Google

CHAPTER XVIII.

Governors.

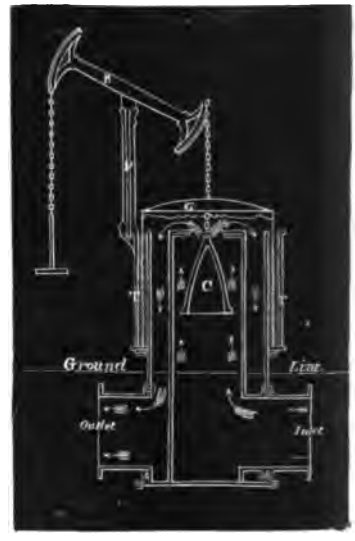
As the pressure of the gas within the holder, due, as has been stated, to the weight of the latter, is, or should be, greater than is needed for effective distribution, and as, moreover, it is necessary to adapt this pressure to a varying consumption, means have to be provided for its regulation at the

FIG. 151.



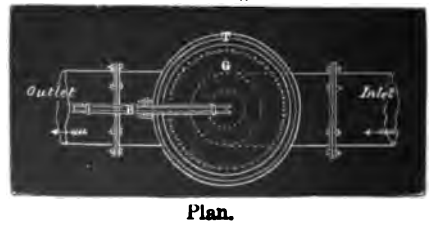
Elevation.

FIG. 152.



Section.

FIG. 153.



Plan.

Governor.

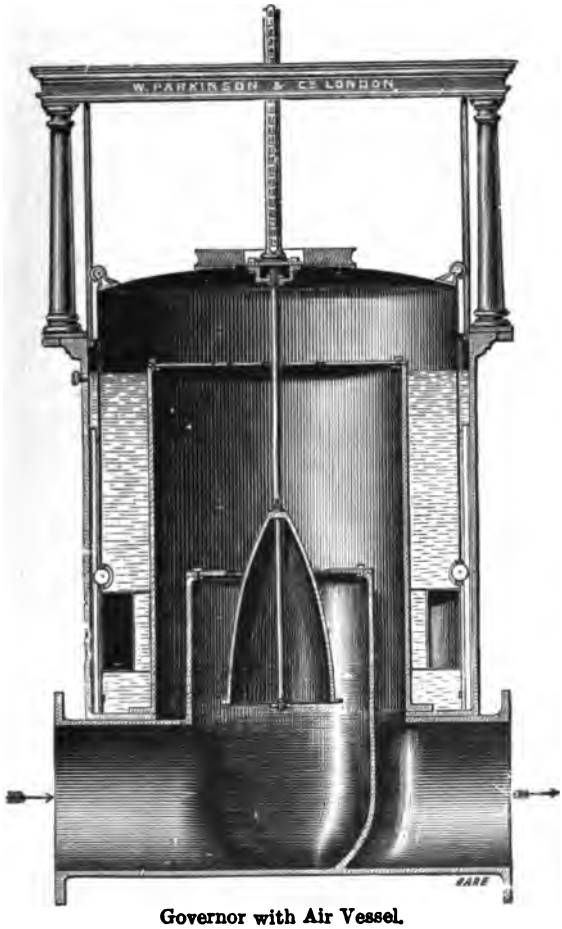
outlet of the gasholder, or entrance to the distributing mains. It is sometimes considered sufficient to interpose a valve, capable of being adjusted with considerable nicety, but usually an apparatus called a "governor" is employed, the object of which is to ensure uniformity of pressure under variations of consumption.

Figs. 151, 152, and 153, show a governor of ordinary construction, although an air vessel is very frequently used, as in Fig. 154, in place of the cross-arm and counterpoise. It consists of a miniature gasholder, G, called a bell, contained in a cast-iron tank T, partially filled with water. From the centre of the bell is suspended a conical valve C, which fits exactly,

Digitized by Google

when at its full height, into the aperture of the inlet-pipe, diminishing or increasing the size of the aperture as the bell rises or falls. When the bell is exactly balanced, no gas can pass through the governor, because the slightest pressure exerted on the inlet raises the bell to its full height, and completely closes the valve; accordingly, any pressure that may be required at the outlet is obtained by increasing the effective weight of the bell, and this is done by reducing the counterpoise *w*, or, when the balance is effected

FIG. 154.



Governor with Air Vessel.

by an air vessel, by placing weights on the crown of the bell, Fig. 154. Thus, if a pressure at the outlet equal to one inch head of water be required, a weight equal to that of a column of water one inch in height over the area of the bell must be added to the latter, by one of the two methods indicated, according to the construction of the governor. This being done, the pressure may be expected to remain constant under any variations of consumption. When it is desired to alter the pressure, the effective weight of the bell must be readjusted accordingly. In practice it is only necessary to maintain a pressure of from $\frac{7}{10}$ths to $\frac{12}{10}$ths or $\frac{13}{10}$ths during the daytime, but towards evening this has to be gradually increased to two or three inches, according

Digitized by Google

to circumstances, at which it is maintained during the first few hours of darkness, or the period of heaviest consumption, and is again brought down by successive reductions as the consumption falls off. These alterations are very conveniently effected by means of water, which, as required, is caused to flow into, or out of, a tank placed on the top of the bell.

In Fig. 154, the valve is seen to be suspended at a considerable distance beneath the crown of the governor bell, so that the inlet aperture is sufficiently below the top of the inlet pipe to admit of a free passage for the gas from inlet to outlet without entering the bell. This arrangement has been devised for the purpose of obviating the tendency to undue movement of the bell in any alteration of inlet pressure such as is occasioned by changing the delivery of the gas from one gasholder to another, or when a telescopic gasholder is "cupped" or "uncupped." This tendency arises from the suspended valve not being in equilibrium, a portion only of the upper surface being exposed to outlet pressure, while the remainder, together with the whole of the under side, is acted on by inlet pressure. Any appreciable alteration of the latter consequently tends to set the bell in motion, not unfrequently causing considerable unsteadiness of pressure. As shown in the illustration, the outlet pipe is covered by a plate having a centre opening sufficiently large for the free working of the suspension rod of the valve, and also to secure the necessary equality of gas pressure. The gas having no other means of passage to and from the bell but by the small annular space surrounding the suspension rod, acts as a kind of cushion to resist any rapid motion of the bell, which would otherwise be unrestrained. This arrangement likewise affords security against tilting of the bell, since the gas that could in such case escape must be limited to the quantity passing through the small centre opening, whereas with the ordinary governor the whole area of the inlet would, under similar circumstances, be exposed.

FIG. 155.

Hunt's Equilibrium Governor.

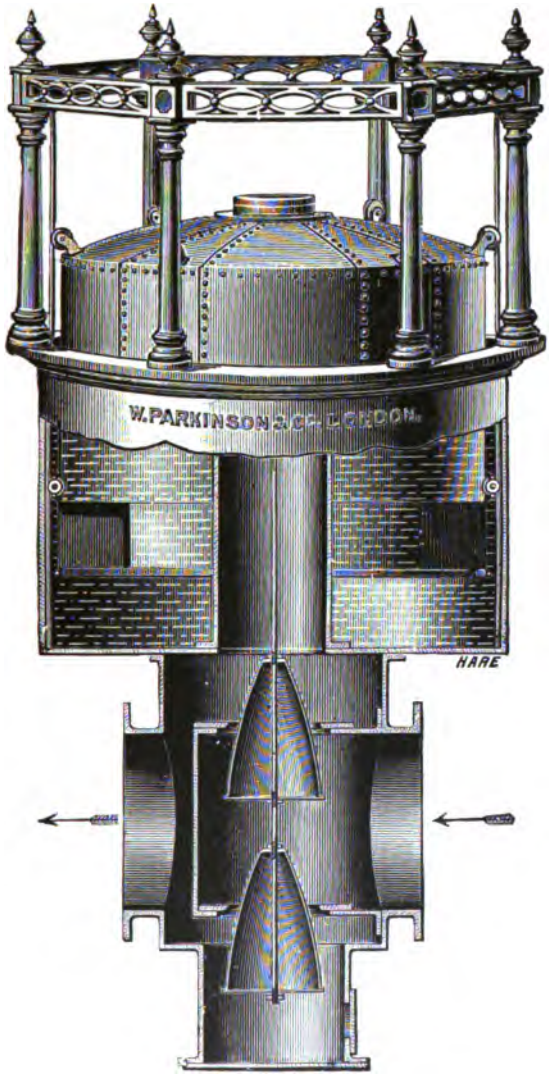
Hunt's Equilibrium Governor, Fig. 155, secures the same advantages of safety and freedom from undue movement, while by the substitution for the suspended valve of a throttle valve, which is accurately balanced upon steel centres, the outlet pressure is maintained without alteration under variations of inlet pressure. This is a very compact form of governor, requiring little more space than an ordinary slide valve.

Governors which effect the same objects as the foregoing have been devised by Messrs. W. and B. Cowan, Messrs. J. and J. Braddock & Co., and others. Fig. 156 shows the double cone equilibrium governor designed by Messrs. W. Parkinson & Co. In this governor the stream of inlet gas is divided, and passes equally through two valves fitted one above the other. The inlet pressure acts therefore on the top of one valve and on the bottom of the other, equilibrium being thus secured. In Messrs. J. and J. Braddock's governor, Fig. 157, a compensating chamber, of the same area as the valve, is attached to the centre of the bell, which chamber, as well as the top of the valve, is subject to inlet pressure. The remainder of the bell is placed in communication with the outlet by means of a narrow pipe. Fig. 158 shows Braddock's new patent gas station governor in section and also n

Digitized by Google

elevation. It consists of a gas chamber divided by a partition *B*, forming an inlet part *A* and an outlet part *A'*, communicating with the distributing main. In the partition *B* are two openings *C* and *D*, fitted with faced seatings, and provided with parabolic valves *E* and *F*, the former closing

FIG. 156.

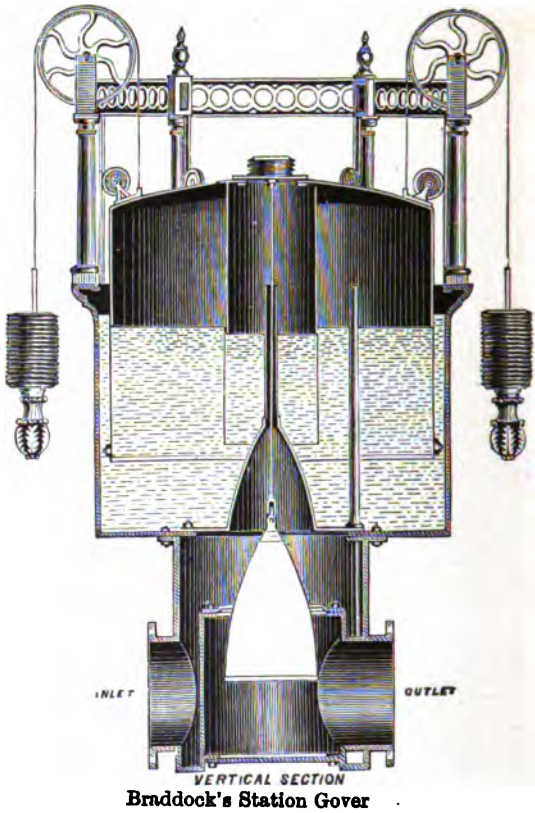


Parkinson's Double Cone Equilibrium Governor.

downwards and the latter upwards, through which the gas passes in the direction of the arrows, from the inlet to the outlet. The valves are connected at *H H* to the two opposite ends of a balance beam *I*, centrally supported at *K*, on the pillar *L*. The rods *G G* of the valves *E* and *F* pass out of the chamber *A* through ordinary water-seals in the top of the outlet chamber. But the water-tank *M'* is made of a larger diameter than

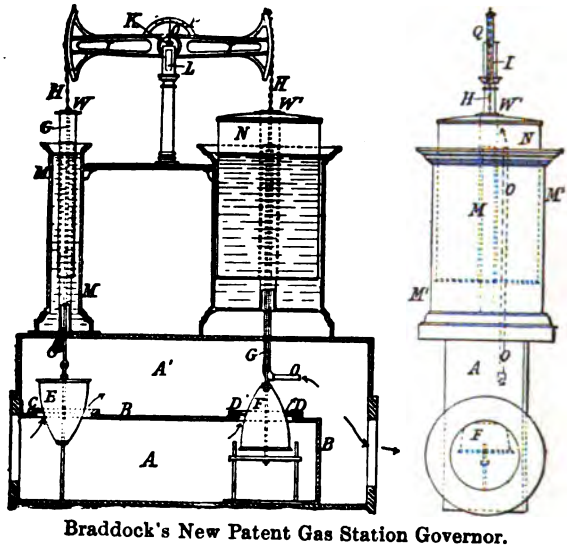
Digitized by Google

FIG. 157.



Braddock's Station Gover

FIG. 158

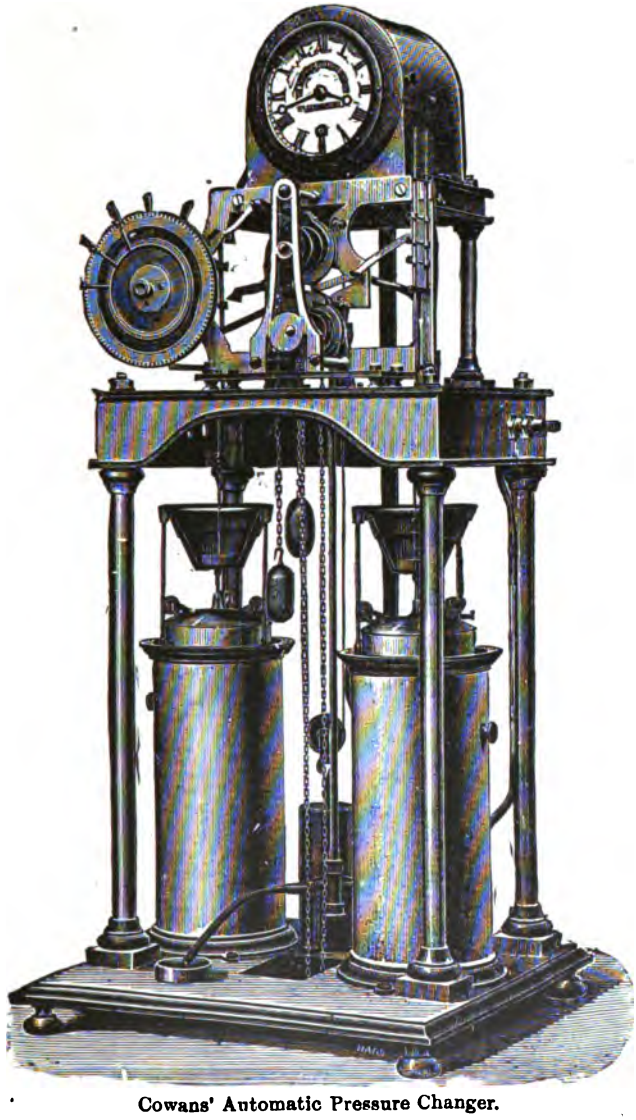


Braddock's New Patent Gas Station Governor.

Digitized by Google

the water-tank *M*, and to the top of the valve-rod which passes through it is attached a bell or receiver *N*; into which gas is admitted by means of a pressure-controlling tube *O*, open at both ends, and connected to the top of the outlet chamber *A'*. The weights to give the desired outlet pressure are

FIG. 159.



Cowans' Automatic Pressure Changer.

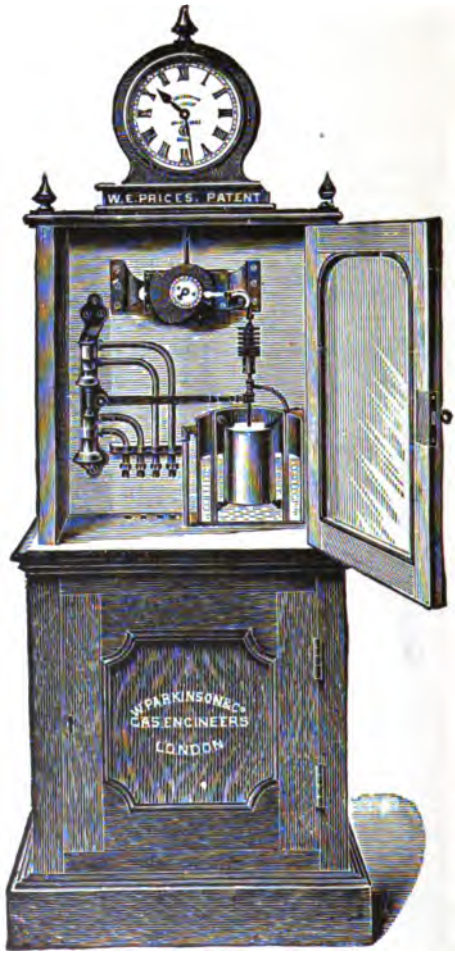
placed at *W'*, or at *W* when they act in the opposite direction. This arrangement of two valves balancing each other, and acting in opposite directions in combination with a bell or receiver, obviates the necessity for heavy valves and counterbalance weights, and thus diminishes the size and bulk of the apparatus.

The pressure, in inches of water, given by a governor, is equal to the effec

Digitized by Google

tive weight of the bell divided by the weight of a column of water one inch in height distributed over its area; and as the bell is either counterpoised, or balanced by an air vessel the capacity of which must represent the displacement of an equal weight of water, the required pressure is obtained by adding a weight equivalent to that of a quantity of water

FIG. 160.



Price's Automatic Pressure Changer.

covering the entire area of the bell to the same depth as the required pressure, thus:

Let P = the required pressure in inches,
Let W = the required weight in lbs.,
And A = area of bell in feet;
Then W = P × A × 5.21 lbs., 5.21 lbs. being the weight of a square foot of water 1 inch in depth.

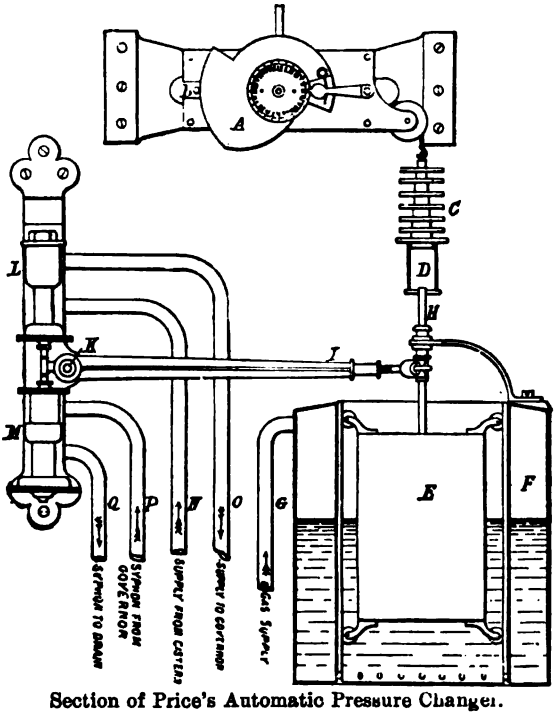
Fig. 159 shows Cowans' Automatic Pressure Changer, which loads and unloads the governor automatically, and so produces the exact pressure

Digitized by Google

required and at the proper times, the necessary changes being produced with exactitude both as to time and degree.

When the pressure has to be raised, the instrument automatically opens a tap through which water flows into the roof-tank of the governor bell until the desired pressure is produced, and the tap is thereby closed. In like manner, when the pressure has to be lowered, another tap is opened, through which water is withdrawn by means of a syphon, and when the desired reduction in the pressure has been made, this tap, like the other, is closed automatically. Any number of such changes, between the lowest and the highest desired, can be made with the apparatus, with all the necessary variations as to time. The mechanism which opens the tap is operated

FIG. 161.



Section of Price's Automatic Pressure Changer.

by the clock, while that which closes it is set in motion by the gasholders, which rise or fall as the pressure is raised or lowered.

Price's Automatic Pressure Changer, Figs. 160 and 161, is another instrument designed for the same object.

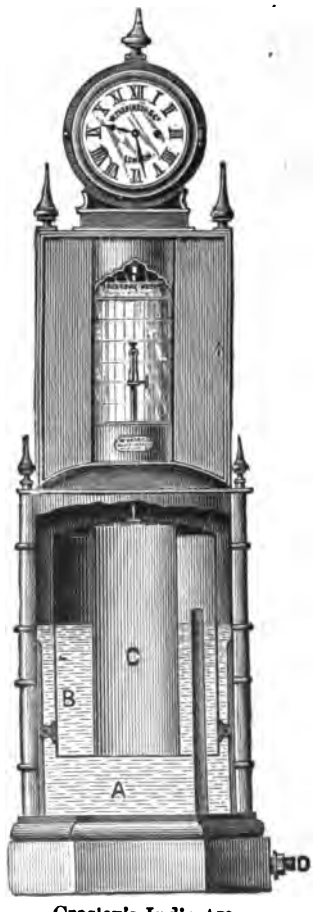
Self-registering pressure indicators are employed to indicate to the manufacturer the pressure at which the gas is sent into the mains at all times of the day and night.

Crosley's Indicator.—This is constructed of two small cylinders, the inner one being inverted in water contained in the outer cylinder, and rising and falling with the pressure of the gas conducted into it by a small pipe from the main. A rod attached to the top of the movable cylinder carries at the end of it a pencil, which bears upon another small cylinder rotated by clockwork once in twenty-four hours, and covered with a sheet of paper ruled vertically to correspond with the hours of the day, and horizontally to represent pressure in tenths of an inch As the

Digitized by Google

pressure varies the pencil moves up and down, producing a corresponding line on the paper. This arrangement is shown in Fig. 162, which is partly in section, for the purpose of explanation. A is the outer cylinder or tank, within which is the holder B. In the centre of the holder is a cylindrical float or air vessel C, by which the weight of the holder and pencil rod are accurately balanced, whilst D is the inlet pipe for the gas, the pressure of which raises or lowers the holder;

FIG. 162.



Crosley's Indicator.

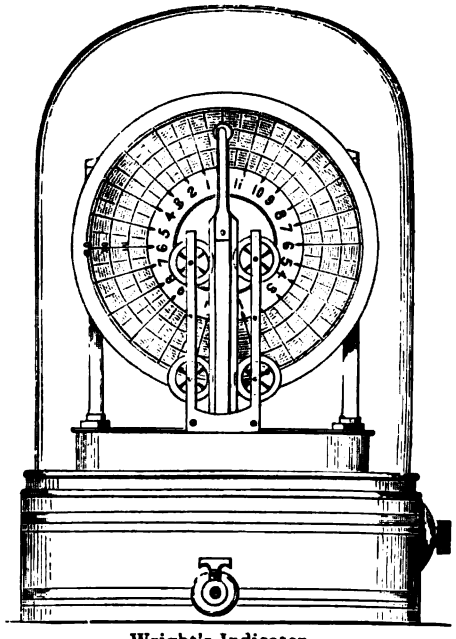
by varying the proportions of the latter in relation to the tank, the pressure can be recorded with any degree of amplification that may be required. Thus the pencil is usually made to traverse a space greatly exceeding one-tenth of an inch in height for every actual tenth of an inch pressure. This is found to be of great advantage when observations of slight variations of pressure require to be made.

Wright's Indicator.—The pressure indicator, Fig. 163, known as Wright's has a circular disc, rotated once in twenty-four hours on a horizontal axis moved by clockwork; and its construction differs in other respects from that of Crosley's. A float, having attached to it a pencil rod, is placed in a

Digitized by Google

central chamber open at the top to the atmosphere, and communicating at the bottom with an enclosed annular space, partly filled with water. The gas, being admitted into this space, depresses the water therein and correspondingly elevates that within the central chamber, thus raising the float according to the pressure, and causing this to be marked by the pencil on the disc, which is furnished with a ruled paper having divisions corresponding with the twenty-four hours of the day and night, and with the pressure in tenths of an inch.

FIG. 163.



Wright's Indicator.

By thus recording the pressure maintained at different periods during the twenty-four hours, these instruments are of service in securing regularity and uniformity of supply. They are also used, in a modified form, to record the working of the exhauster, and serve as a check on the man in charge of this apparatus. For this purpose greater buoyancy must be given to the holder in the case of Crosley's, and on both registers the zero point, instead of being at the bottom, as in the pressure register, is placed about half-way up, the lines above indicating pressure, and those below indicating exhaust.

CHAPTER XIX.

Distributing Mains and Pipes.

The distribution of the gas from the gasholder or outlet of the governor is effected by means of cast-iron pipes, from whence it is conveyed to the premises of the consumers by wrought-iron or leaden service pipes. For interior fittings the pipes are either made of lead, hardened by the addition of a little antimony, or of wrought-iron.

Very much of the success of a gas undertaking depends on the efficiency of its distributing plant, because with pipes badly laid or insecurely jointed or insufficient in size, much loss of gas inevitably results. It was no uncommon thing at one time for the gas unaccounted for to amount to a fourth or even to a third of the quantity actually produced; but by greater care and vigilance, combined with increased skill and better judgment in the selection of methods, the loss has now been greatly reduced. It may, in fact, be regarded as a reproach to many undertakings of appreciable size, working under ordinary conditions, to have to acknowledge a greater proportion of gas unaccounted for than ten or twelve per cent. Six or seven per cent. is considered fairly good working, but there are instances in which the loss is not more than three or four per cent.

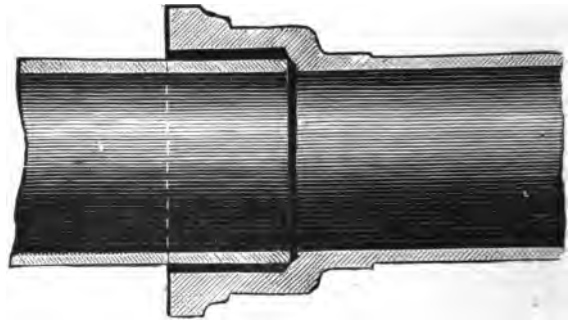
This improvement is in part attributable to more perfect registration of

Digitized by Google

the quantity consumed, and the more strict adaptation of the pressure to the varying requirements of the consumers; but it is mainly owing to a better appreciation of the necessity of paying as much attention to the condition of plant buried below the surface of the ground, as of that which is open to daily, or even hourly, inspection. Neglect of ordinary precautions, such as the periodical examination and renewal of all perishable material, has been a fruitful source of loss in the past, but is now happily of rare occurrence.

On the introduction of gas-lighting into London, Winsor used pipes made of sheet lead bent round a mandril and soldered at the edges. Murdoch's first pipes were made of tinned iron, and in Paris pipes made of tinned sheet iron with riveted edges, and with a coating of asphalt, are still largely used; but in this country in a very short time cast-iron pipes were substituted. These, as now employed, vary in thickness according to their diameter, from

FIG. 164.



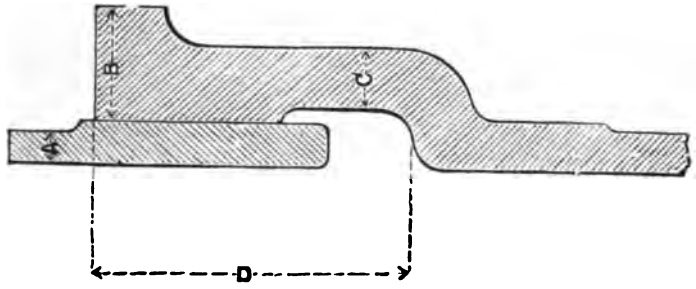
Cast Iron Pipe showing Joint.

$\frac{3}{8}$ inch to $\frac{7}{8}$ inch, and are generally cast in a vertical position, by which equality of thickness is ensured. The smaller sizes are in 9-feet lengths; those of about 12 inches diameter and upwards being in 12-feet lengths. They are jointed together by means of a socket cast at one end of the pipe, the other end being termed the spigot. The spigot end of one pipe being inserted into the socket of another, as shown in Fig. 164. leaves an annular space between the pipes, usually about $\frac{3}{8}$ths of an inch in width. Into this a strand of yarn is tightly caulked and driven in to the back of the socket. The opening is then temporarily closed with a band of clay and the remainder of the space filled in with molten lead. This, when cooled, is "set up" all round with a caulking tool and hammer, all superfluous lead being trimmed off with a cold chisel. A joint thus made possesses a certain degree of elasticity, which renders it proof against the minor disturbances to which gas mains are liable; besides which it is convenient because, the socket and spigot not being tightly fitting, it allows of a slight deviation of the line of pipe to the right or left, as occasion may require. Another method of jointing occasionally used is the turned and bored joint, Fig. 165, which is chiefly applicable to straight lengths of main. This was introduced by Alfred King, in the year 1826, and effects, it is stated, a considerable saving in the cost of laying the pipes. As will be seen by the illustration, the socket and spigot are made tightly fitting, the spigot having an extra thickness of metal to admit of its being turned down with a very slight taper, the socket being bored out to suit. Both parts of the joint are smeared over with red or white lead paint, and the spigot is then driven smartly into the socket with a wooden mallet applied to the other end of the pipe. This completes the process.

Digitized by Google

All main pipes should be firmly bedded in the soil, and at a sufficient depth beneath the surface to prevent injury from traffic or alteration of temperature. In no case should less than 18 inches of covering be provided, and where the ground is liable to subsidence, or the traffic is exceptionally heavy, or where a heavy steam roller is employed for repairing the roads, a greater depth, more especially for mains of small diameter, is

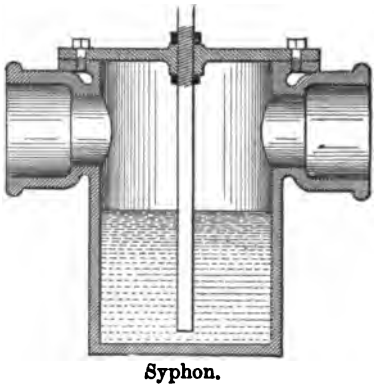
FIG. 165.



King's Turned and Bored Joint.

often advisable. It is necessary to insert syphons or receivers, Fig. 166, at suitable intervals, towards which the mains should be laid with a slight incline, so that any water or other liquid which may accumulate through leakage or condensation may drain into the syphon. By means of a wrought-iron pipe, shown in the figure, extending nearly to the bottom of the vessel, to which a pump may be attached when needed, the receiver can be periodically emptied of its contents.

FIG. 166.



Syphon.

In flowing through the pipes, the gas is subjected to friction against their sides, which increases rapidly as their diameter diminishes. As it is both inconvenient and wasteful, because of the leakage it occasions, to overcome, by increased pressure, the diminution of velocity caused by friction in the current of gas, it becomes necessary to so arrange the capacity of the pipes that the velocity at different distances from the works may not sensibly vary, and it is therefore of importance to be able to calculate the effects of friction.

The relations between the dimensions of the pipe, the pressure of the gas, and the velocity diminished by the effect of friction, &c., have been made the subject of repeated experiments by engineers, and the practical mathematical formula which is most conformable to the experimental result is, according to Pole * :

$$Q = 1350\, d^2 \sqrt{\frac{h\, d}{s\,(l + d)}}$$

* "Journal of Gas-Lighting," 1852, ii. 352.

Digitized by Google

In which

Q = Quantity of gas passing per hour in cubic feet
l = Length of pipe in yards.
d = Diameter of pipe in inches.
h = Pressure in inches of water.
s = Specific gravity of gas, that of atmospheric air being 1.

This equation may be translated in the following manner:—

1. Multiply the pressure by the diameter of the pipe, both in inches.
2. To the length of the main in yards add the diameter in inches, and multiply the sum by the specific gravity of the gas. Divide the product by the result of (1), and extract the square root of the quotient.
3. Multiply the square of the diameter of the pipe in inches by the constant coefficient 1350, and divide by the result of (2). The quotient will be the quantity discharged in cubic feet per hour.

The experiments cited by Pole in illustration of the above equation are given in the following tables:—

Experiments on Atmospheric Air.

No.	Diameter of Pipe.	Length of Pipe.	Pressure in inches of Water.	Quantity actually discharged.	Quantity calculated by equation.	Difference per cent.
	Inches.	Yards.		Cubic Feet per hour.	Cubic Feet per hour.	
1	0.62	7.2	1.34	183.0	170.0	7½
2	„	41.0	„	73.0	72.0	1
3	„	62.0	„	62.0	60.0	3
4	„	93.0	„	52.0	49.0	6
5	„	119.0	„	42.0	43.5	4
6	„	138.0	„	39.0	40.2	3
7	„	141.0	„	38.7	39.8	3

Experiments on Coal Gas.

No.	Diameter of Pipe.	Length of Pipe.	Pressure in inches of Water.	Specific Gravity of Gas.	Quantity actually discharged.	Quantity calculated by equation.	Difference per cent.
	Inches.	Yards.		Air = 1.	Cubic Feet per hour.	Cubic Feet per hour.	
1	0.62	41	1.34	0.559	99	99	0
2	„	62	„	„	83	81	2
3	„	93	„	„	74	66	12
4	„	119	„	„	57	58	2
5	„	138	„	„	53	54	2
6	18.0	1,760	1.0	0.4	66.000	69,000	4½
7	4.0	10,560	3.0	0.4	852	1,140	25
8	0.5	10	1.25	0.4	120	129	7
9	„	59	„	„	60	55	8
10	10.0	100	3.0	0.4	120,000	112,000	7
11	„	1,760	3.0	0.4	30,000	28,000	7
12	2.0	25	0.5	0.528	1,630	1,440	11½
13	26.0	3,130	0.8	0.42	103,000	114,000	10
14	„	4,300	2.25	„	175,000	166,000	6
15	„	„	0.475	„	80,000	76,000	5

The above experiments on atmospheric air were tried by M. Girard in Paris, and are recorded in D'Aubuisson's "Hydraulique," Art. 525.

Experiments on Coal Gas, 1 to 5, were tried in Paris at the same works as those on atmospheric air.

No. 7 is recorded in "Clegg." This is the only case in which the results of experiment and calculation differ considerably from each other. It must be noticed

Digitized by Google

that the pipe is of very great length (six miles) in proportion to its diameter; and it is, therefore, quite possible that the disturbing causes spread over so great an extent may have been more numerous and important than was supposed. At any rate, this is evidently an exceptional case.

The following shows experiment No. 11 worked out in figures as an example:

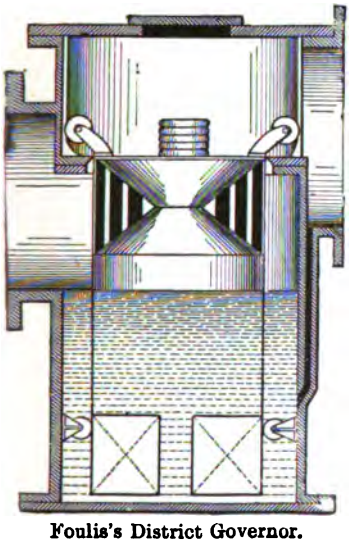
1 $3 \times 10 = 30$

2 $\sqrt{\frac{(1760 + 10)\,0.4}{30}} = \sqrt{23\,6} = 4.86$

3. $\frac{100 \times 1350}{4.86} = 28{,}000$ nearly.

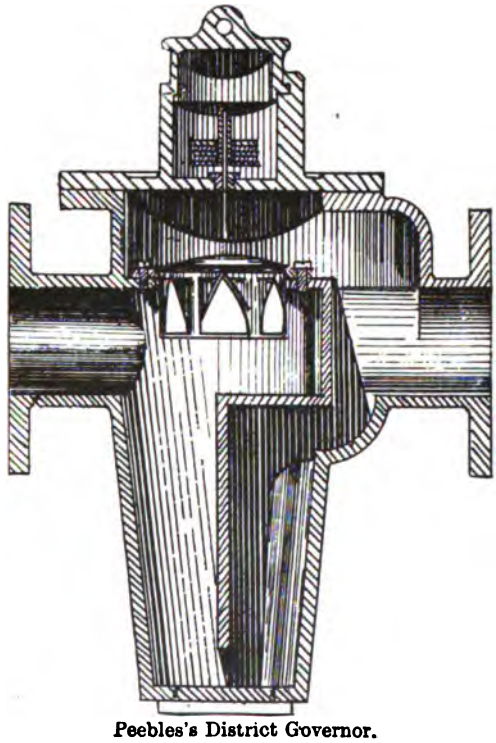
All causes which tend to produce eddies or disturbance of the even flow of the gas check the velocity and diminish the discharge; for this reason

FIG. 167



Foulis's District Governor.

FIG. 168.



Peebles's District Governor.

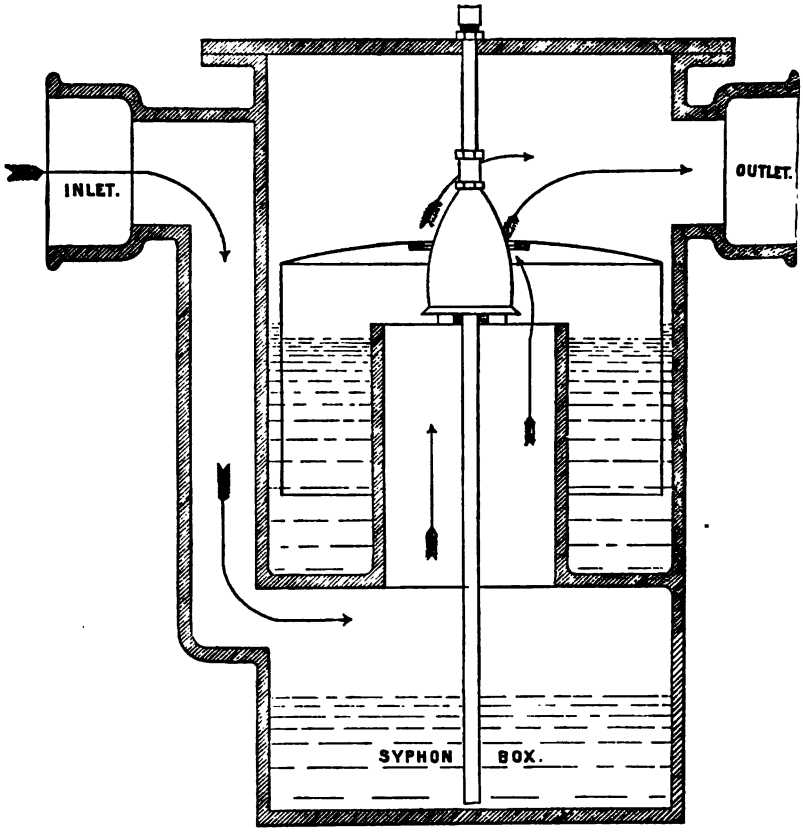
sharp bends or contractions should be avoided as much as possible. Alterations of level affect the pressure to the extent of about one-tenth of an inch for every ten feet of vertical height. This requires to be taken into account when the capacity of a distributing main has to be determined. The accession of pressure which takes place in rising ground is valuable as overcoming the effect of friction, and hence the desirability of placing gasworks at or below the level of the lowest point it is desired to supply, by which the opposite effect, of a diminished pressure owing to a descent, is at the same time avoided. When considerable irregularities occur in the level of a district, it often becomes necessary to reduce the pressure in the more elevated por-

Digitized by Google

tions, and this is done by inserting a "district" governor into the distributing main.

District Governors.—There are several different forms of this instrument, the object of which is to produce at the outlet of the governor a constant

FIG. 169.



SECTION.

Jones's Differential Governor.

reduction of pressure as compared with the inlet. Fig. 167 shows Foulis's, of which the following is a description:*

"The valve is formed of two inverted cones, having a cylindrical prolongation with the necessary float, the object of making the cone double being to neutralise the effect of the inlet pressure; or, in other words, to prevent the inlet pressure from exerting any influence on the action of the governor. In order further to attain this object, the triangular space formed by the two cones is enclosed by a continuation of the cylindrical portion of the valve. In this slits are cut of sufficient area, and so adjusted that when the valve is open to the full the area of the portion of the slit below the valve seat is rather greater than that above it, thus establishing a uniform pressure in the triangular space, and so equalising the pressure on the two

* King's "Treatise on Gas Manufacture," vol. ii. p. 427.

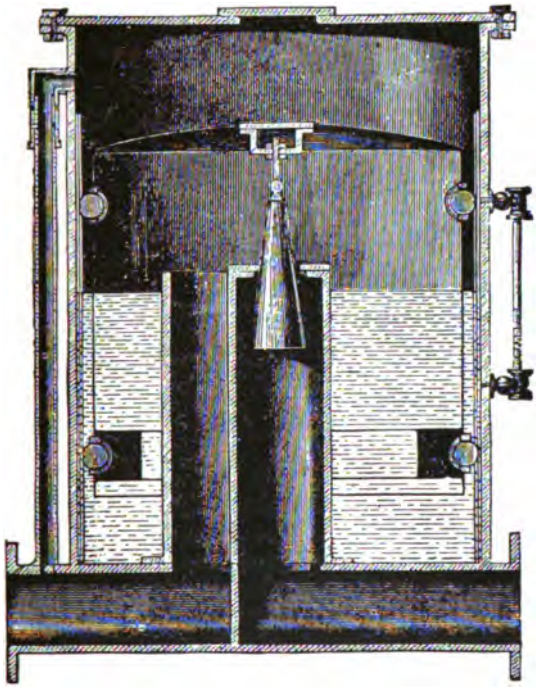
Digitized by Google

conical surfaces. The vessel is charged with glycerine to prevent freezing. When the orifice shown immediately below the valve is open to the inlet gas, and the float loaded to the required amount, the governor is differential in its action; that is to say, the difference between the inlet and outlet pressures is constant, thus enabling the pressures on the district governor to be reduced to any required extent below that at the works."

Fig. 168 illustrates Peebles's district governor.

Jones's differential governor is shown in Fig. 169, which will explain its action. When placed in the line of main it serves also the purpose of a

FIG. 170.



Parkinson's District Governor.

receiver, any accumulation of water being pumped up from the bottom of the tank by means of the wrought-iron pipe upon which are carried the conical valves.

Fig. 170 shows the district governor made by Messrs. W. Parkinson & Co., which has the valve suspended from the bell, in the same way as in an ordinary governor.

Service Pipes.—The service pipe by which the gas is conveyed from the main to the premises of the consumer is attached by drilling or cutting a hole in the top or side of the cast-iron pipe. The hole is first rymered to the exact size, and then tapped with a suitable thread, when a bend or straight piece, according to the position of the hole, is screwed into it, the joint being made secure by previously smearing the thread with a mixture of red and white lead. In the early days of gas lighting, and before the introduction of the present method of manufacturing wrought iron tubes, old gun barrels screwed together were not unfrequently employed as

Digitized by Google

services. Not many years ago some of these were unearthed in one of the streets of Birmingham. When leaden service pipes are used, a brass union takes the place of the wrought-iron bend or straight piece, and to this the lead pipe is secured by a plumber's joint. Too much care cannot be bestowed on these attachments, as, if improperly made, they become a fruitful source of leakage. Lead pipes, from their tendency to sag under the weight of the superincumbent earth, often require to be supported upon a lath of wood. When subsidence is allowed to take place, water is likely to accumulate, and block the passage of the gas.

Wrought-iron service pipes, although less costly than lead, are not nearly so durable, and in some soils they decay very rapidly, often requiring to be renewed every few years. To prevent this destruction, with its attendant loss of gas, the plan has been extensively adopted of laying them in V- or U-shaped troughs, made of thin laths nailed together, which, after the pipe has been laid, are filled up with hot tar, previously boiled almost to the consistency of pitch.

Occasionally stoppages occur in the service pipes caused by an accumulation of water, condensed liquid hydrocarbons, or naphthalene. It is then necessary to disconnect the service and send a blast of air from a suitable force pump through the pipe, the obstruction being thus blown into the main.

Naphthalene.—In many places no little annoyance is caused during particular seasons of the year (in some places principally in the spring and autumn, and in others in the summer), by stoppages of services and even of mains by accumulations of naphthalene. This substance, which is produced by the action of heat upon various hydrocarbons, condenses in such a voluminous condition that it may occupy a space four thousand times greater than an equal weight of water—a very little, therefore, sufficing to prevent the passage of gas through a service pipe. This nuisance is of comparatively recent origin, and seems to have appeared concurrently with another known as stopped ascension pipes.

The connection between these two most pronounced of the difficulties of gas-making may not at first sight appear very clear, nevertheless it would be tolerably safe to say that there does exist a somewhat intimate, if hitherto undefined, relationship between them. Naphthalene deposits, it is true, do not uniformly make their appearance concurrently with stoppages in the ascension pipes, a circumstance which may be capable of explanation by reference to temperature and means of condensation of the gas; but they rarely, if ever, occur where no trouble exists with the latter. Moreover, the two phenomena are alike objects of dread to the gas-maker, who has groped his way to deliverance from them—if deliverance he has really found—by means the very diversity of which only serves to prove the extreme complexity of the problem with which he has to deal. One thing seems beyond dispute, namely, that both sources of trouble are alike traceable to increased temperature of carbonisation as compared with that employed in the earlier days of gas manufacture. These changed conditions have, however, come to be regarded as essential to economy, and hence the opinion has found expression that stopped pipes and naphthalene deposits are evidences of good management. This conclusion can hardly be accepted as satisfactory or as disposing of a subject which is, upon more than one account, of the highest importance.

The troublesome obstructions in the pipes through which the gas passes from the retorts to the hydraulic main, forming what are commonly known as stopped pipes, are due to a pitchy deposit which is the first result of the cooling process the gas undergoes from the first moment of its leaving the

Digitized by Google

retort. That this deposit is attributable to a deficiency of certain hydrocarbon vapours, which ordinarily act as carriers to the heavy carbonaceous portion of tar, separately designated as pitch, appears probable from the fact that the best known methods for obtaining relief from it are—(1) the placing in the mouthpiece of the retort a lump of coal or cannel, which is distilled at a very low temperature, with production in abundance of light tar; or (2) placing in the same position a few pieces of coke well soaked in common petroleum or naphtha. Moreover, it seldom occurs to any extent when coal is carbonised at a temperature sufficiently moderate to cause production of tar having a comparatively low specific gravity. On the other hand, something is perhaps due to the proportion of cooling area afforded by the mouthpiece and ascension pipe. The author once had experience of a case in which one large ascension pipe had been applied to three retorts, in place of one pipe of the usual dimensions to each retort. It proved a complete failure, for not only was it blocked up with pitch after a very short time, but the hydraulic main, and even the foul main behind, also filled up with pitch, which had to be literally dug out every second or third week.

Assuming, however, as seems reasonable, that these stoppages are mainly to be attributed to an insufficiency of condensable hydrocarbon vapour in the volatile products as they issue from the retort, the question arises, what is the cause of this deficiency, and is it beneficial or otherwise to the general result? To the first part of this question the answer is supplied by the fact that, with the same coal, or the same class of coal, increase of temperature of carbonisation means a less production of tar, which is of a higher specific gravity and contains but a small proportion of light oils. Whether such increase of temperature is beneficial or otherwise to the general result is probably a question of degree only, since all experience warrants the statement that, within limits, more illuminating value is obtained at a high than at a low heat. (See p. 20.)

Naphthalene is not found in tar which is produced at a very low temperature, but occurs in other tars in quantity varying from about 5 to 10 per cent. According to Mr. Watson Smith * there are, notwithstanding variations according to the coal used, "strong evidences of the general rule that with tar of moderate specific gravity (1.16 to 1.17) we have a large yield of that tar, a good yield of gas of high illuminating power, and a moderate amount of naphthalene, with doubtless a good yield of anthracene, and a fair amount of benzene and carbolic acid, whilst with one of high specific gravity, the gaseous volume is larger, illuminating power smaller, naphthalene (and anthracene) larger, and the amount of tar obtained smaller."

Since, according to Berthelot and others, the production of naphthalene is due to the decomposition of benzene and acetylene, with liberation of free hydrogen, within the retort, it naturally occurs to ask in what form are the hydrocarbons of most light-giving value, in that of naphthalene, or of the first named compounds? According to Mr. H. Leicester Greville, 1 lb. of naphthalene is equal in illuminating value to 17 lbs. of sperm. If it were possible for the whole of it to be delivered to the consumers' burners, probably little need be said against the employment of a temperature which causes an exchange, so to speak, from one light-giving material to another, although there might still remain to be considered the comparative inconvenience of working at high heats. As a matter of fact, however, only a very small proportion of that which is produced can possibly escape all the precautions which modern

* Jour. Soc. Chem. Ind., vol. viii. p. 953.

Digitized by Google

ingenuity has devised for effecting its removal before the gas leaves the works. That which does so escape is more often than not a source of great trouble and expense, from its tendency to deposit in the mains and service pipes under the influence of a sudden reduction of temperature. The most effectual preventive of such deposits, both within and without the works, has been found to be gradual cooling of the gas in contact with the tar, and a uniform reduction of temperature to a maximum of, say, 55° F. An American engineer (Mr. Young), speaking on this subject, states that although he was greatly troubled with naphthalene deposits, when he arrested the cooling process during winter at 65°, he ceased to have any trouble at all from this cause after he adopted the plan of cooling the gas as low as the temperature of the water used in his condensers permitted. All this of course points to the removal of the naphthalene from the gas by means of the light oils which go to enrich the tar; and thus, as has been well stated by the "Journal of Gas-Lighting," "we are in the anomalous position that a sufficient quantity of one illuminant—namely, light oils,

FIG. 171

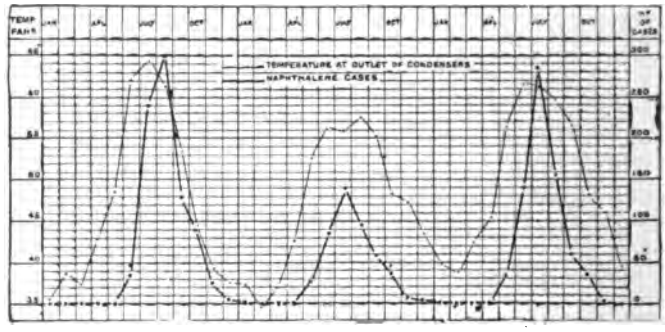


Diagram showing the monthly fluctuation in the number of naphthalene cases, and in the temperature of gas at outlet of condensers during a period of three years.

which have been shown by Mr. Leicester Greville to possess an illuminating value nearly equal to that of benzene, or about twelve times that of sperm, should be left in the tar, in order to secure the removal of another illuminant—that is naphthalene. The manufacture of illuminating gas as at present conducted is open to the charge of wastefulness; as it is an unavoidable feature that considerable quantities of illuminating matter must be allowed to pass into the tar-well."

High heats, then, appear to be accountable for the following:

(1) Reduction in the quantity of light oils, by reason of the formation of naphthalene, &c., from decomposition of benzene, &c.;
(2) Stopped pipes, resulting from a deficiency of light oils;
(3) Withdrawal of light oils from the gas, consequent on the necessity for removing naphthalene; thus involving considerable loss of illuminating matter.

There is no doubt but that the illuminating matter produced at moderate temperatures of distillation is capable of more permanent retention in the gas than naphthalene and the other high heat products, and judging from observation of working results, it would appear that there is a limit to the heat that should be applied in the distillation of coal, varying no doubt with the description of the latter, within which the best results, as to

Digitized by Google

quantity and quality of gas and yield of tar and ammonia, are obtained, and beyond which it is not advisable to go. If also, as seems probable, the extent of this limit is fairly well defined by the occurrence of stopped pipes and naphthalene deposits, these may be regarded as in the nature of warnings which no prudent gas manager can afford to despise.

As showing the influence of temperature upon deposits of naphthalene the above diagram (Fig. 171) may not be uninteresting.

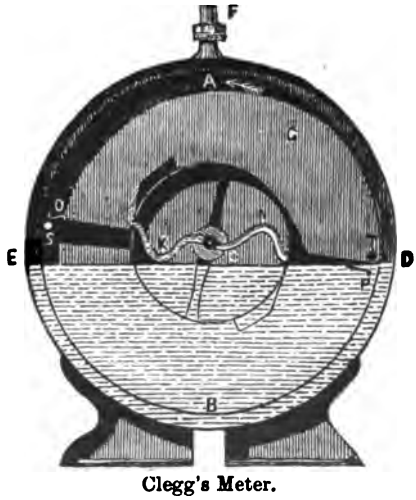
M. Brémond, in 1877, accounted for the deposits of naphthalene in the mains and service pipes, by supposing it to be formed synthetically, at the moment of condensation, at lower temperatures, of the aqueous vapour held in suspension by the gas. A more likely explanation seems to be that the aqueous vapour acts mechanically on the naphthalene held in suspension, and that upon a lowering of temperature the condensed water vapour carries down naphthalene which otherwise would have remained in suspension. Be that as it may, however, M. Brémond is fully entitled to the credit of having proved by careful experiment that gas which is deprived of its aqueous vapour, by passing through quicklime or other absorbent, does not deposit naphthalene. This, although proposed for use as a remedy, has not hitherto been practically applied.

CHAPTER XX.

Gas Meters.

For a considerable period after the introduction of gas-lighting, the only way of ascertaining the quantity of gas used by each consumer was by the size and number of the burners used and length of time of ignition. This method was unsatisfactory, owing to the impossibility of recording with sufficient exactness either the consumption of the burners under different pressures, or the number of hours during which these were lighted. A system of accurate measurement was much needed, and the want of it greatly retarded the extension of gas-lighting.

FIG. 172.



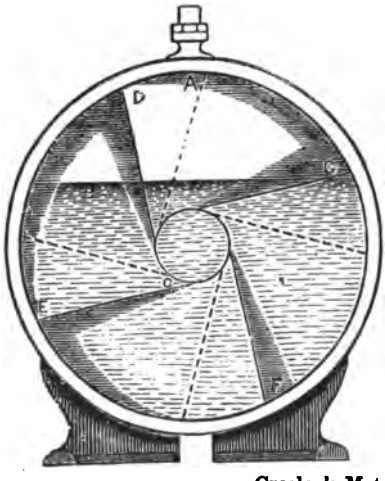
Clegg's Meter.

Clegg's Meter.—Clegg was the inventor of the first self-acting machine for the measurement of gas. In 1815 he took out a patent, in the specification of which two different kinds of meters are described, both actuated by the pressure of the gas. One of these was much too complicated for use; but the other is the first usable gas-meter of which there is any record. It is shown in Fig. 172, and was what is known as a "wet" meter, the instrument being partly filled with water. The cylinder or drum AB, contained in the case DE, revolved upon a hollow axis C, which served as the inlet for the gas; the outlet being at F. By means of two bent tubes KN, the inlet communicates with two semicircular chambers, these being separated by partitions, having two valves, OP, through which the

Digitized by Google

water passes from one chamber to the other as the drum revolves. As shown in the illustration, the gas passes into the chamber having the valve P, which closes as the partition rises out of the water. The gas in the chamber under the valve O escapes through the hole S into the case, and leaves the meter by the outlet F. The bent tube K is sealed against the passage of the gas, by means of the small trough above it, which, in its passage through the water, becomes filled to be emptied into K upon attaining the necessary position. When the valve O in its turn enters the water, the gas is discharged through the hole T into the case; so that one compartment is being filled while the other is being emptied. The cubical contents of the drum above the water line being known, and the number of revolutions

FIG. 173.



Crosley's Meter.

FIG. 174

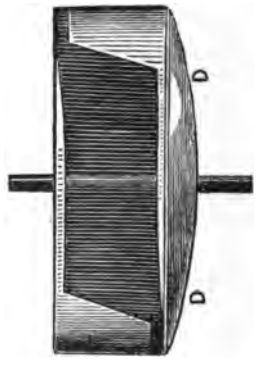
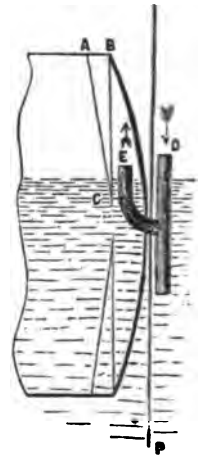


FIG. 175.



Section of Crosley's Meter.

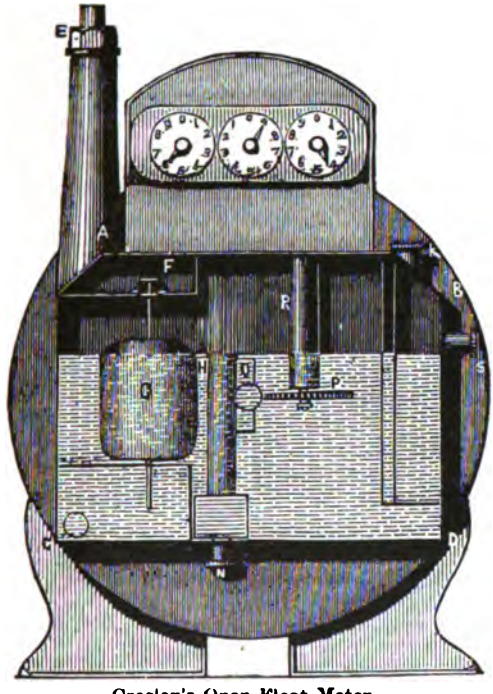
made by it recorded by means of wheel-work attached to the hollow spindle, the amount of gas burnt can be ascertained. Malam improved considerably upon this meter, and introduced into it the principle of the Archimedian screw, abolishing the stuffing-box, valves, and bent tubes.

Crosley's Meter.—To Samuel Crosley, however, who purchased the patent rights of Clegg, belongs the credit of having brought the wet meter to its present state of perfection. Fig. 173 shows a front view of the drum of Crosley's meter, but without the hollow cover which enclosed it. Fig. 174 is a part section of the drum, exposing one of the compartments, the hollow cover being shown at DD. The drum is divided into four compartments, the partitions of which are placed at an angle, thus offering very little resistance to the passage of the drum through the water. There is likewise space in the centre of the drum for the free passage of the water from one compartment to another. The inlet and outlet spaces—to the front and back of the drum respectively—are arranged so that there is no free passage through the drum without moving it, and are shown by the radial lines DEFG, in Fig. 173, which indicate the position of the openings through which the gas passes to the compartments behind. These openings are shown in section at ABC, Fig. 175; the gas being introduced into the inlet openings by means of the bent tube or spout ED. The water level requires to be always above the hole in the hollow cover through which the spout passes, as otherwise gas would pass through the drum

Digitized by Google

without setting it in motion. Although in other parts of the machine many variations have been made in detail, most of these having for their object the regulation of the water level, the drum, as above described, has remained practically unaltered, and is almost universally used in wet meters at the present day. Parkinson has reduced the number of compartments from four to three, by which the friction in working is diminished, as likewise the cost of manufacture. The size of the drum is calculated according to the number of burners the meter is intended to supply; hence the term "three light," "five light," "ten light," and so on; the "light" being always understood to mean that which is produced by a burner consuming six cubic feet of gas per hour. Thus a five-light meter will supply gas at the rate of

FIG. 176.



Crosley's Open Float Meter.

thirty feet per hour. The capacity of the smaller sized meters is calculated at a speed of about 150 revolutions per hour, but the larger ones decrease in the number of revolutions per hour as they increase in size.

The measuring capacity of the drum is practically unaltered, except by a variation of the water level, and the index shows only the number of revolutions of the drum, without taking into account the observance of the due proportions of water and gas. To keep the water at the proper level in the meter is therefore a matter of the utmost importance, and various means have been devised with that object. Fig. 176 shows the arrangement originally adopted by Crosley, and known as the "open float." As will be seen from the illustration, a square box, ABCD, is fixed to the front of the cylindrical case containing the drum. At the corner A the gas enters, and passes through a valve F, which is worked by a float G placed below it, and is so balanced that when, by evaporation or otherwise, the water level falls below a given point, it shuts the valve and so closes the passage of the

Digitized by Google

gas. Below the water-line is an opening from the square frame into the drum case behind, so that the water finds the same level in both. The gas fills the upper part of the square frame, passes down the pipe H, and up through the spout into the drum, as shown in Fig. 175, where the line OP represents the division between the drum case and the square frame. The meter is filled with water at the plug K, Fig. 176, and at the plug N any water that may rise above the pipe H is drawn off. The side plug S is for adjusting the correct water-line of the meter, which is obtained by first filling the meter with water, and then leaving out the plug S until no more water will run out of it.

On the end of the drum shaft is placed a worm O, working into a cog-wheel P, which, by means of a spindle through the tube R, turns the index at the top. In a three-light meter, for example, the measuring drum revolves eight times for every cubic foot; the wheel on the spindle has forty teeth, and consequently the latter makes one revolution for every five feet of gas passed. A worm on the top of the spindle works into a wheel of thirty teeth, which therefore revolves once with every 150 cubic feet; on this there is a pinion of six working into a wheel of forty teeth, and to the axle of this wheel is fixed the first hand on the dial, which consequently makes a complete revolution for every 1000 cubic feet of gas passed through the meter.

This meter was open to the objection that it could be tampered with, in the interests of the consumer, by the withdrawal of water by means of a syphon-pipe inserted at K, and in the interests of the seller by overfilling with water regardless of the plug S. With the object of overcoming this objection Crosley, in the year 1837, adopted the "bird fountain" principle for keeping the water at the proper level. The reservoir was placed above the meter with a tap between the two, which was closed when the reservoir was taken off to be replenished. Since that date many contrivances have been devised with the same object, of which a few of the more prominent may be referred to.

Esson's Meter.—In this meter the "bird fountain" principle is adopted. An air-tight reservoir is placed in the upper part of the square front, and connected therewith by an air-pipe. When the water in the meter, by evaporation or from any other cause, falls below its proper level it unseals the lower mouth of the air-pipe, up which gas finds its way into the reservoir, allowing water to descend into the meter, until the proper water level is again restored.

Sanders and Donovan's Compensating Meter.—The compensating meter of Sanders and Donovan (Figs. 177 and 178) acts by means of a compensating float A, upon which is carried a valve B. The float is of semi-cylindrical form, turning on a horizontal axis X, which is mounted at or near the level of the liquid in the meter. The weight of the float is so adjusted that when it is in its highest position, with its flat side or diameter horizontal, it will balance itself on the axis, and when the diameter is vertical one half will be immersed and will support the other half. As the water evaporates so the float descends, displacing a sufficient quantity of water to maintain a constant water level. Upon attaining its lowest position the valve B comes into contact with the valve seat C, and closes the passage of the gas.

Clegg's Hydraulic Meter.—Clegg, the inventor of the wet gas-meter, patented, in 1858, a new hydraulic meter. The measuring drum was divided into five compartments, and in the centre of it was placed an air vessel by which it was balanced in the water at a constant level, and rose or fell according to the quantity of water in the meter.

Warner and Cowans' Meter.—In Warner and Cowans' meter the drum A (Figs. 179 and 180) is similar to that of an ordinary meter, but

Digitized by Google

FIG. 177.

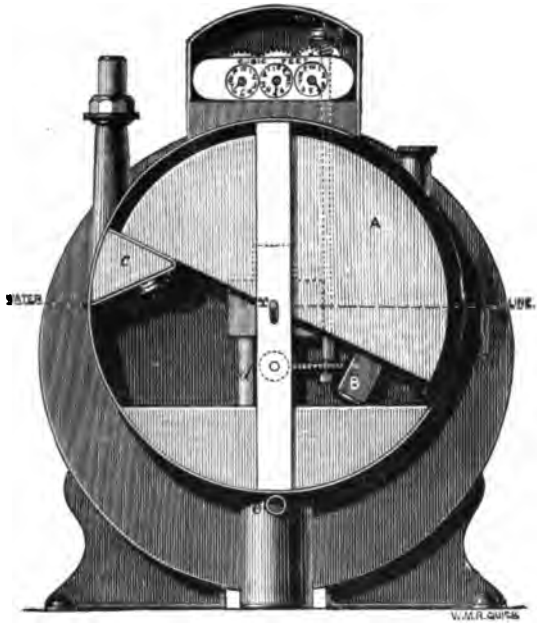
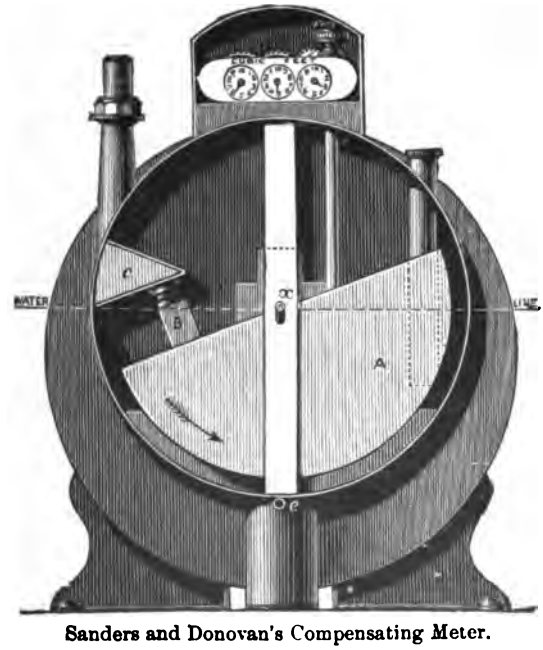


FIG. 178



Sanders and Donovan's Compensating Meter.

Digitized by Google

within it is placed a smaller drum B, of similar construction, only with a

FIG. 179.

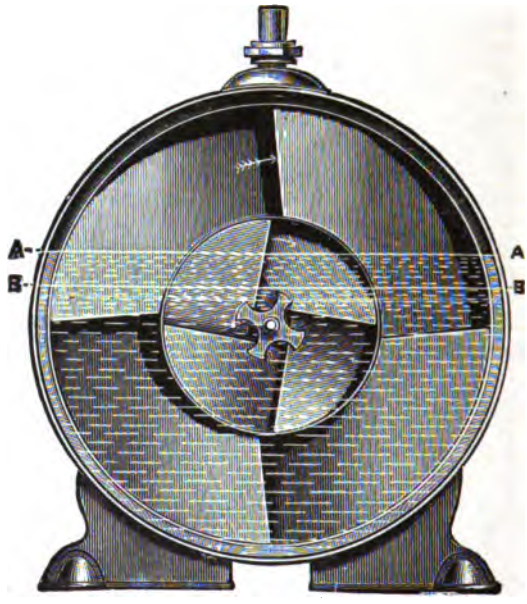
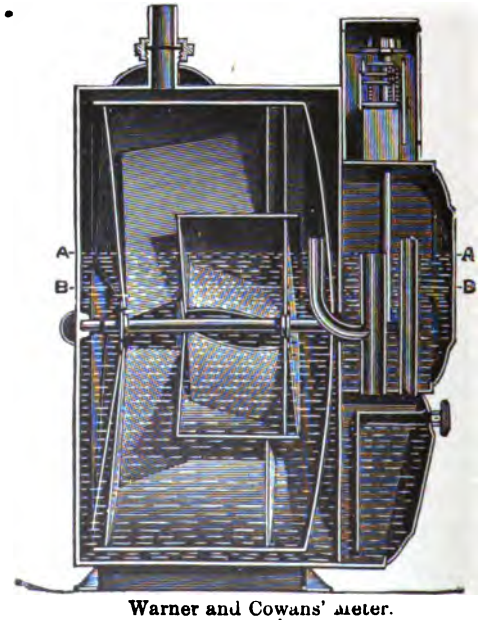


FIG. 180.



Warner and Cowans' Meter.

reverse action, so that it takes its supply from the filled compartments of the larger drum, thus returning gas to the inlet. Both drums being equally

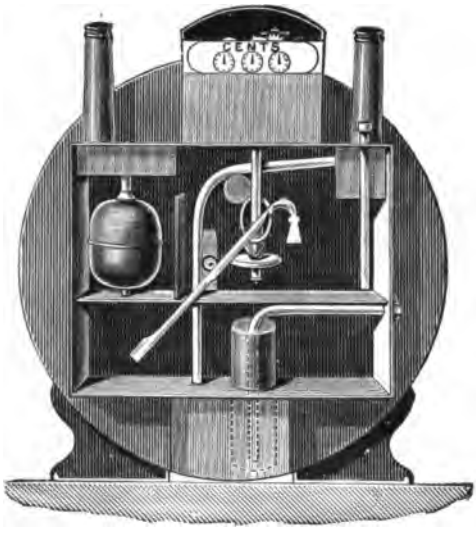
Digitized by Google

affected by alteration of water level, the one acts as a compensator to the other, any increase or diminution of measuring capacity of the larger drum being compensated for by a corresponding diminution or increase of that of the smaller drum.

Mead's Meter.—A very satisfactory compensating arrangement is that invented by Mead in the year 1851, consisting of a "spoon" or "scoop" actuated by a cam fixed to the upright spindle, by which, at every revolution of the shaft, a small quantity of water is lifted from a reservoir and discharged into the measuring chamber, thus maintaining the proper water level in the latter, so long as the reservoir remains charged with water.

Hunt's Compensating Meter.—In Hunt's compensating meter, patented in 1877, this spoon is employed; but in addition the range of the float is reduced, and accurate registration at varying speeds and pressures is ensured by reversing the action of the measuring wheel, previously accomplished by Urquhart in his "Reliance" meter. Fig. 181 shows this arrangement, in which the gas enters the body of the meter through the valve chamber, and passes through the bent tube to the outlet. In this way the pressure of the inlet gas bears equally upon the whole surface of the contained water, thus preventing any undue alteration in the measuring chamber which, in the ordinary meter, results from the inequality of area acted on by the inlet and outlet pressure. Tests made with this meter, at pressures varying from 5 to 30-tenths, and the quantity of gas passing per hour ranging from the nominal capacity up to nearly 2½ times this capacity, show a variation in the registration of only 0.20 per cent.

FIG. 181.



Hunt's Compensating Meter.

In the year 1859 was passed the "Sale of Gas Act," by which the standard cubic foot for gas measurement was fixed as equal to 62.321 lbs. of distilled water, weighed in air at the temperature of 62° F., under a barometric pressure of 30 inches. Under its provisions public inspectors were appointed throughout the country for the examination and stamping of gas-meters, and standard testing gasholders—to which have since been added standard testing meters—certified as being correct by the Astronomer Royal, were lodged at the Exchequer. These are employed for verifying all testing gasholders and meters used by inspectors appointed under the Act, which must all bear the Exchequer stamp. The Act also defines the tests to which every meter must be subjected before stamping. It orders that the test for capacity shall be made at five-tenths pressure while the gas is passing through the meter at the rate per hour stated thereon as its proper working speed, and no meter may be stamped if it shows a variation of more than 2 per cent. fast or 3 per cent. slow. To comply with these requirements it is necessary that when the water level is raised high enough for the meter to register 2 per cent. fast, the water should overflow the pipe H, Fig. 176

Digitized by Google

(p. 189), and when it has fallen low enough for the meter to register 3 per cent. slow, the float G should fall and close the valve. With such narrow limits, however, much inconvenience is caused to the consumer on any access of pressure, by the partial closing of the valve, and to remedy this Pinchbeck introduced the improvement which is shown in Figs. 182 and 183. The gas

FIG. 182.

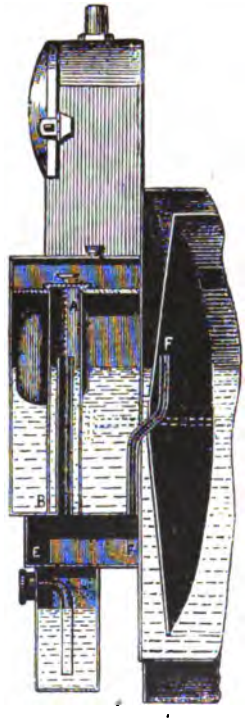
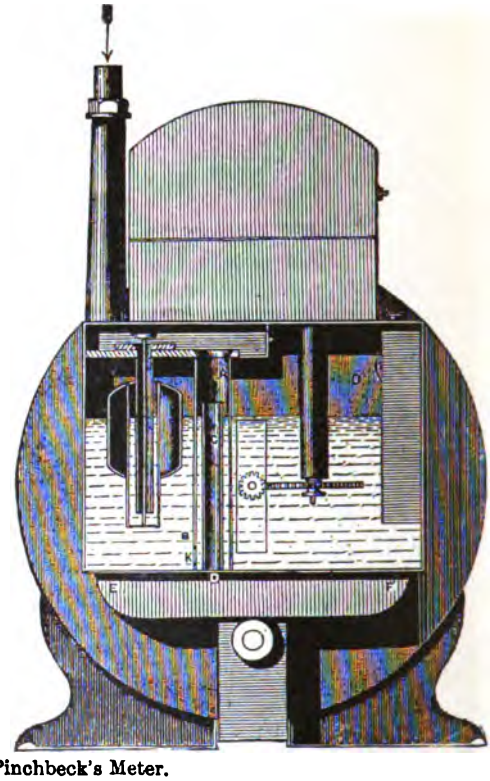


FIG. 183.



Pinchbeck's Meter.

passes through the valve, as in Fig. 183, but instead of filling the front chamber it passes into the pipe AB, through the inner pipe CD into the waste water-box E, and is then conveyed by the pipe F into the measuring drum. The action of the float is thus reversed, because instead of being depressed it is raised, by an increase of pressure. This arrangement enables the meter to comply in all respects with the requirements of the Sale of Gas Act.

Dry Meters.

Although the wet meter is unexceptional in point of accuracy, its use is not without inconvenience. It requires to be periodically supplied with water, and in very cold weather the water is liable to be frozen, when the passage of the gas is completely stopped; moreover, the pipes which convey the gas from it to the consumers' burners must be laid with an inclination towards it from every part, so as to secure the return of any water that

Digitized by Google

may be taken up by the gas in its passage through it, and deposited by condensation. Otherwise this water would remain in the pipes and block the passage of the gas. Much ingenuity has been exercised in the construction of a variety of measuring instruments, in which the use of water or any liquid is dispensed with.

Clegg's Meter.—Clegg displayed remarkable ingenuity in the construction of what may be called a dry gas-meter, and which is shown in Figs. 184 and 185, and thus described by the inventor :—

FIG. 184.

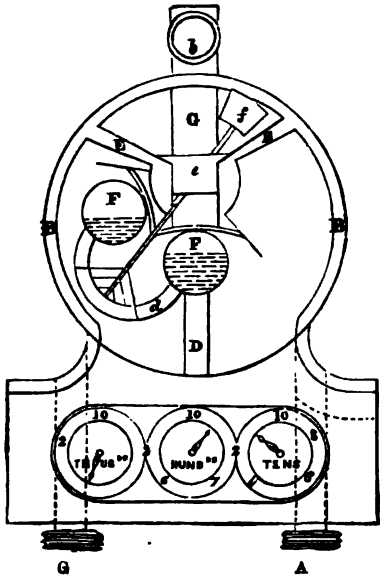
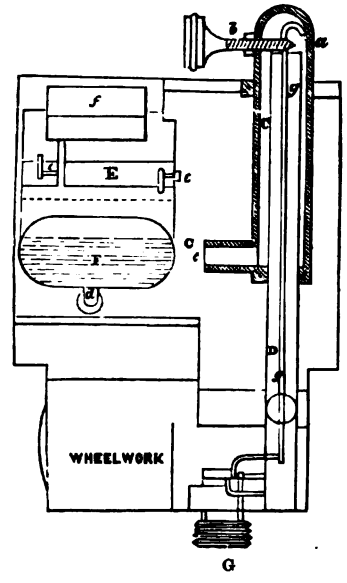


FIG. 185.



Clegg's Dry Meter.

"In a small cylindrical vessel two glass cylinders, connected together by a bent tube *d*, exhausted of air, and half filled with alcohol, are made to vibrate on centres *e* and *e*, and are balanced by a weight *f*. An excess of heat applied to either cylinder causes the liquid to flow into the other, upon the principle of Leslie's differential thermometer. C is a hollow brass box called the heater, projecting about one inch above the cylindrical meter. At *a* issues a small jet of gas, which, when inflamed, gives motion to the cylinders.

"The gas enters the meter by the pipe A, and circulates throughout the double case B; having passed round the case B, a portion of it enters the top of the box C by the pipe D, and passes out again at the bottom by the tube C into the meter; the rest of the gas enters the body of the meter through holes in the curved faces of the hoods EE, and, after blowing on the glass cylinders, passes to the burners by the outlet pipe.

"To put the meter in action, let the jet *a* be lighted about an hour before the burners are wanted. In most cases this jet will be lighted all day as a useful flame. The hole *a* is so situated on the box C, that, whatever be the size of the jet, a fixed temperature is given to the box, that temperature depending on the quantity of flame in contact with the box, and not on the length of the jet. The jet being lighted, and the box C heated, the gas

Digitized by Google

which passes through it is raised to the same temperature and, flowing out at the tube C, impinges on the glass cylinder which happens for the time to be the lower; the heated gas soon raises a vapour in the lower cylinder, the expansion of which drives the liquid into the upper one, until it becomes heavier than the counterpoise *f*. When the cylinders swing on their centre, the higher one descends and comes in the line of the current of hot gas, and the lower one ascends; the same motion continues as long as the jet *a* burns. The same effect on the cylinders is maintained, however the outward temperature may change, by the cold gas, which, issuing from the curved side hood EE, impinges on the upper cylinder, and hastens the condensation of the vapour which it contains.

"The cold gas and the heater vary in temperature with the room, and thus counteract each other.

"The lighting of the jet *a* is essential to the action of the meter: in order to ensure this, the supply of gas to the burners is made to depend on it in the following manner:—The pipe G, by which the gas leaves the meter, is covered by a slide-valve, which is opened and shut by the action of the pyrometer *g*; the pyrometer is in communication with and receives heat from the jet, and opens the valve when hot, closing it again when cold.

"The speed at which the cylinders vibrate is an index of the quantity of heat communicated to them, and is in exact proportion to the quantity of gas blowing on them through the pipe C and curved side of the hoods EE.

"The gas passed through the heater is a fixed proportion of the whole gas passing the meter; therefore the number of vibrations of the cylinders is in proportion to the gas consumed.

"A train of wheel-work, with dials, similar to that used in the common meter, registers the vibrations.

"Simplicity, accuracy, and compactness are the most remarkable features of this instrument, and the absence of all corrosive agents will ensure its durability."

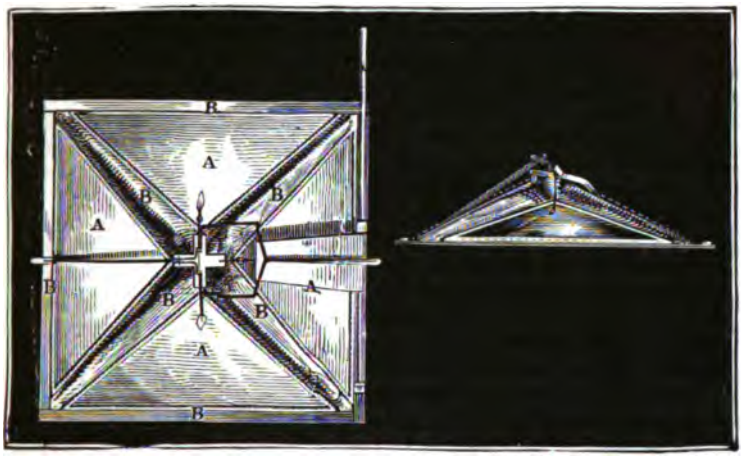
In the instrument, however, now known as a dry gas-meter, the gas is measured by the number of times that a certain volume will fill a chamber capable of undergoing contraction and expansion by the passage of the gas. These alternate contractions and expansions resemble the action of an ordinary bellows, and set certain valves in motion, which regulate the flow of gas in much the same way as the valves of a steam engine regulate the admission and discharge of steam to and from the cylinder.

Defries's Dry Meter.—The first dry meter was invented by Malam in the year 1820, but this was never perfected, and subsequent attempts were not much more successful. Defries' meter, however, was well calculated for affording accurate measurement. It consisted of three measuring chambers, separated from each other by flexible partitions of leather, partially protected the machinery in action, and measures the amount of gas which passes from the chemical action of the gas by metal plates. The metallic protection is shown at A in Fig. 186, and the flexible leather at B. The pressure of the gas expands the flexible partition, which then assumes the form of a cone, as represented by the small side cut; the motion of this flexible cone backwards and forwards on both sides of its base sets through the meter. The object in introducing three chambers into the meter is, that its action may be continuous, like that of a three-throw pump, and free from that oscillation of the lights which sometimes results from the use of two chambers.

Croll and Richards' Meter.—This meter, patented in the year 1844, is, with slight modification, the dry meter most largely used at the present time. It consists of an outer case AA, Fig. 187, made of tinned iron or soft

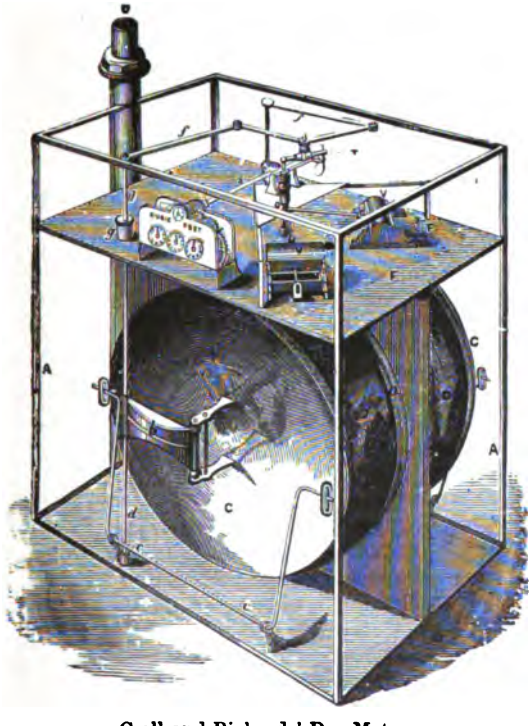
Digitized by Google

FIG. 186.



Defries's Dry Meter.

FIG. 187.



Croll and Richards' Dry Meter.

Digitized by Google

steel, divided by a horizontal partition F, into two compartments. In the upper of these are the sliding valves VV, through which the gas passes to and from the measuring chambers. The lower portion of the meter is divided by a centre vertical partition into two chambers, in each of which is a movable diaphragm DD, rigidly attached to the centre partition, and closed at the opposite end by a metal disc C. These metal discs serve the purpose of pistons, and are kept in their places by a kind of universal joint attached to each; the space through which the discs move by the action of the gas, which affords the means of measurement in this meter, is governed by the guides *cc*, and by the rods *d*, and arms *ff*. To avoid the friction attending on pistons working in a cylinder, a band of leather DD is attached, which acts as a hinge, and folds with the motion of the disc; this band is not instrumental in measuring the gas, so that its contraction or expansion would only decrease or increase the capacity of the hinge, so long as the disc is at liberty to move through the required space. The leather is also attached in such a manner that it can only bend in one direction, and this renders it much more durable.

The machine is quite comparable to a steam engine measuring its steam, which it may be said to do by the strokes of the piston. The gas enters the measuring chambers at the top, from the space occupied by the arms, valves, &c., and forces the discs bodily forward through a certain space; the motion communicated by the discs to the rods and arms causes the supply of gas to be cut off, and allows it to escape by another valve; at the same moment the gas is admitted to the other side of the disc, and this is forced to return to its original position, traversing, of course, the same space as before. Each backward and forward motion consequently indicates the passage of a constant quantity of gas, and the same mechanism which admits and shuts off the supply by means of valves, is connected with an index, and thus the motion of the disc, or the quantity of gas which has passed through the meter, can be indicated as in the ordinary wet meter.

Various modifications of the meter have been proposed for the purpose of meeting special requirements. In 1885, M. Wybauw, Gas Engineer to the Municipality of Brussels, devised a meter having two indices—one showing the total consumption, the other the night consumption only; the object being to enable gas to be supplied at differential rates for day and night consumption. One hour before the public lamps are lighted, the ordinary night pressure being put on at the works throws the two indices into gear, so that they work together. On taking the pressure off in the morning, one index is thrown out of action, whilst the other continues to register whatever gas passes through the meter. The arrangement being independent of any alteration of outlet pressure, consequent on consumption, and actuated only from the works or by inlet pressure, enables gas to be supplied to premises at two different prices, according to the time when the supply is afforded.

Parkinson's Pressure Raiser, Fig. 188.—This is the application of a wet meter to work as an exhauster, drawing the gas from the main, and propelling it according to the pressure required. The drum of the meter is revolved by multiplying wheels and pulleys, actuated by a weight, as shown in the illustration. The pulleys may be arranged so as to keep the apparatus at work for many hours, if the weight has sufficient fall.

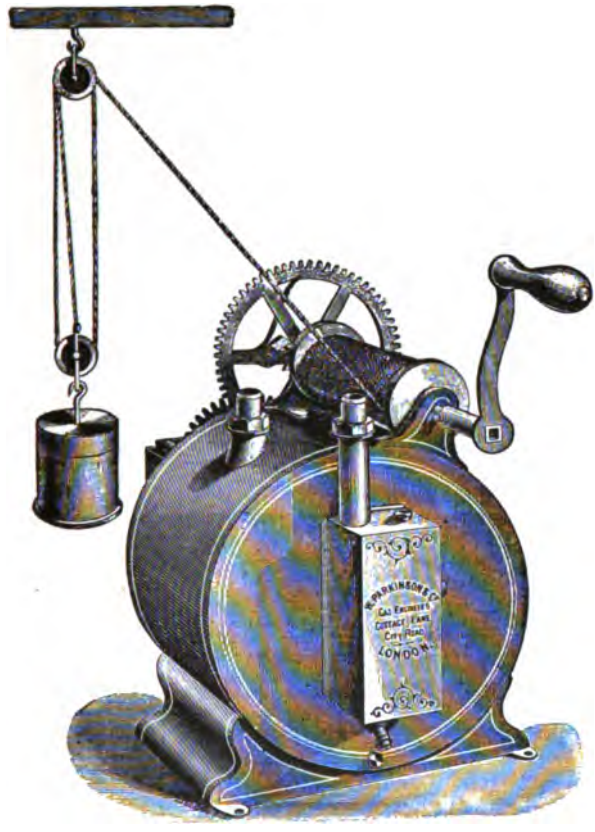
Prepayment Meters.—These meters were introduced with the object of encouraging the use of gas amongst householders of the artisan class, by arranging for payment of the gas consumed in instalments adapted to their means and habits. The meter thus became what is called a "prepayment" meter, the idea being derived from the well-known automatic sweetmeat

Digitized by Google

machines, which are actuated by means of a penny dropped through a slot. They very quickly acquired popularity—so much so that the South Metropolitan Gas Co. alone, during the two years ending December 1894, fixed no less than 25,500, and in June 1899 had upwards of 86,000 in use.

Mr. W. R. Brownhills patented the first prepayment meter. In his arrangement a movable stop gearing is attached to the upright spindle

FIG. 188.



Parkinson's Pressure Raiser.

of a wet meter in such a manner that the stop can only be disengaged by the weight of a penny-piece bearing upon a lever, where it is moved round by the action of a spring which has to be pressed down each time after a penny has been dropped in. Each such action permits the passage through the meter of a quantity of gas proportionate to the price per 1000 cubic feet to which the gearing is adjusted. This arrangement will not accommodate itself to alterations of price, which may be met by change of gearing, or if preferred by fixing the price at what may be expected to be the maximum charge, and reducing to the current charge by the allowance of a discount at stated periods. The gas was also liable to be suddenly extinguished by the action of the stop.

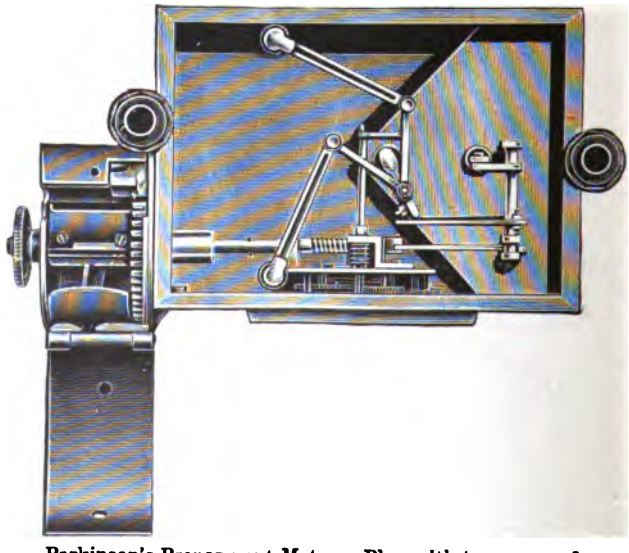
Prepayment meters are now made by all the principal meter manufac-

Digitized by Google

FIG. 189.

Parkinson's Prepayment Meter.

FIG. 190.



Parkinson's Prepayment Meter. Plan with top removed.

Digitized by Google

turers. Figs. 189 and 190 illustrate the arrangement made by Messrs. Parkinson and Co. as applied to a dry meter.

The upper part of the slot-box contains a brass cylinder, Fig. 190, revolving on the same axis as a ratchet-wheel, and turned by the knob placed outside the meter. Upon inserting a penny in the slot, connection is thereby made between the cylinder and the ratchet-wheel, and on turning the knob, the cylinder and ratchet-wheel with its attached spindle are revolved a fixed distance, the penny dropping from the cylinder into the box below, and the spindle opening the gas valve and at the same time registering by means of an index on the scale at the top of the dial plate the number of feet of gas bought (say 25). The quantity of gas bought for a penny may be easily altered when necessary. Twelve pennies worth of gas may be bought in this way at a time, the index then registering 300 cubic feet. As the gas is supplied this index is gradually worked backwards (the indices of the meter, however, registering the quantity in the usual way), and upon nearing the zero the lights are automatically lowered, though plenty of time is allowed for effecting a further purchase before the supply is quite shut off.

CHAPTER XXI.

Enrichment Processes; Oil-Gas, and Carburetted Water-Gas.

It has been shown (p. 20) that, in the carbonisation of coal, with every increase in temperature, within certain limits, an increased value of gas is obtained; and this, notwithstanding a reduction in its illuminating power. The high temperatures used, therefore, in order to obtain such increased value has necessitated the employment of enriching processes in many places where either from necessity or choice, gas of a higher illuminating power is required than is obtained by such practice. Until comparatively recently this enrichment has been effected by the use of cannel, from which gas of a high illuminating value is obtained by the same method as is employed in the carbonisation of common coal; but the increasing scarcity of good cannel, and consequent high prices, has led to the introduction of other means of enrichment.

The principal hydrocarbons which are present in coal gas, or are made use of for enriching it, are given in the following tables (pp. 202, 203):*

Series I. The Paraffins.—The first four members of this series are gaseous at ordinary temperatures, the remaining members given in the table are liquids, whilst higher members are semi-solid or solid bodies, as vaseline and paraffin wax.

These hydrocarbons are "saturated" hydrocarbons (*i.e.*, the combining power of the carbon atoms is completely satisfied), and consequently they do not directly combine with bromine as do unsaturated hydrocarbons.

Coal gas contains from 30 to 45 per cent. of the first member of this series, marsh gas or methane, together with traces of the other gaseous and lighter liquid members.†

The first three or four members of this series form the bulk of the liquids known as gasoline and carburine, the heavier members constituting American burning oil and the denser oil used for gas making.

The researches of Beilstein and of Markownikow have shown, however, that Russian petroleum differs from the American in being largely made up of hydrocarbons of the naphthene series. (Series IIB.)

* Trans. Incorpd. Inst. Gas Engs., 1892, ii. 134.
† G. E. Davis, Jour. Soc. Chem. Industry, 1883, ii. 519.

Digitized by Google

Tables of Hydrocarbons present in, or which may be used for enriching, Coal-Gas.

Series I.—*Paraffin Series—Saturated Hydrocarbons.*
Generic Formula—C_nH_{2n+2}.

Name of Hydrocarbon.	Formula.	Boiling point. Fahrenheit degrees.	Specific gravity. Water = 1.	Illuminating power. Candles, per 5 cubic feet.	Volume of gas at 60° F., 30 inches barometer, from 1 gallon.
					cubic feet.
Methane . .	CH_4	Gas	Gas	5.0*	—
Ethane . .	C_2H_6	,,	,,	35.0†	—
Propane . .	C_3H_8	,,	,,	53.9‡	—
Butane . .	C_4H_{10}	34°	0.6	—	37
Pentane . .	C_5H_{12}	98°–102°	0.626 (62.6° F.)	—	31
Hexane . .	C_6H_{14}	156°	0.663 ,,	—	27
Heptane . .	C_7H_{16}	209°	0.700 (32° F.)	—	25
Octane . .	C_8H_{18}	258°	0.719 ,,	—	22
Nonane . .	C_9H_{20}	297°	0.728 (56.5° F.)	—	20
Decane . .	$C_{10}H_{22}$	331°–334°	0.739 ,,	—	18
Endecane . .	$C_{11}H_{24}$	356°–359°	0.765 (61° F.)	—	17
Dodecane . .	$C_{12}H_{26}$	392°–395°	0.757 (64.4° F.)	—	16

Series IIa.—*Olefine Series—Unsaturated Hydrocarbons.*
Generic Formula—C_nH_{2n}.

Ethylene . .	C_2H_4	Gas	Gas	68.5 §	—
Propylene . .	C_3H_6	,,	,,	—	—
Butylene . .	C_4H_8	,,	,,	123.0 ‖	—
Pentylene . .	C_5H_{10}	91°–108°	0.655 (50° F.)	—	33
Hexylene . .	C_6H_{12}	154°–158°	0.699 (32° F.)	—	30
Heptylene . .	C_7H_{14}	205°	0.739 (63.5° F.)	—	27
Octylene . .	C_8H_{16}	257°	0.723 (62.6° F.)	—	23

Series IIb.—*Naphthene Series—Saturated Hydrocarbons.*
Generic Formula—C_nH_{2n}.

Hexahydrobenzene	C_6H_{12}	156°	0.76 (32° F.)	—	32
Hexahydrotoluene	C_7H_{14}	205°	0.772 ,,	—	28
Hexahydro-isoxylene	C_8H_{16}	244°	0.777 ,,	—	25

Series III.—*Acetylene Series—Unsaturated Hydrocarbons.*
Generic Formula—C_nH_{2n-2}.

Acetylene . .	C_2H_2	Gas	Gas	240	—
Allylene . .	C_3H_4	,,	,,	—	—
Crotonylene .	C_4H_6	64°	—	—	—
Pentene . .	C_5H_8	—	—	—	—
Hexoylene . .	C_6H_{10}	169°–176°	0.71 (55.4° F.)	—	31

* L. T. Wright, Jour. Chem. Soc., xlvii. 200. The pure gas was tested, and consumed in a No. 1 Argand.

† P. Frankland, Jour. Chem. Soc., xlvii. 235. The pure gas was tested, and consumed in a No. 1 Argand. ‡ *Ibid.*

§ *Ibid.* xlv. 530. The pure gas was tested, and consumed in a No. 1 Argand.

‖ W. Foster, Jour. Gas Lighting lvii. 1234. The gas was consumed with an Argand burner.

Digitized by Google

TABLES OF HYDROCARBONS PRESENT IN, OR WHICH MAY BE USED FOR ENRICHING, COAL-GAS—*continued.*

SERIES V.—*Benzene Series—Unsaturated Hydrocarbons.*
Generic Formula—C_nH_{2n-6}.

Name of Hydrocarbon.	Formula.	Boiling point. Fahrenheit.	Specific gravity. Water = 1.	Illuminating Power. Candles, per 5 cubic feet.	Volume of gas at 60° F., 30 inches barometer, from 1 gallon.
					cubic feet.
Benzene . .	C_6H_6	177°	0.884 (59° F.)	349*	40
Toluene . .	C_7H_8	230°	0.872 ,,	—	33
Xylene . .	C_8H_{10}	282°	0.867 (66° F.)	—	29

SERIES VIII.—*Naphthalene Series—Unsaturated Hydrocarbons.*
Generic Formula—C_nH_{2n-12}.

Naphthalene .	$C_{10}H_8$	424°	—	930†	—

Series IIa. The Olefines.—Coal gas contains from 3 to 6 per cent. of ethylene, together with small quantities of the other gaseous and lighter liquid members of the series.‡

Oil gas as made by the Young and Bell process largely consists of ethylene, whilst the lighter liquid members of the series are contained in the oil gas spirit now sold for carburetting coal gas.

Series III. The Acetylene Series.—Acetylene is generally found in coal gas, but the quantity rarely amounts to more than one-tenth per cent. The lighter liquid members of the series are found in the "hydrocarbon" which separates from oil gas upon compression.§

Comparing those hydrocarbons of Series I. II. and III., which contain an equal number of carbon atoms in the molecule, it will be observed that a great increase in illuminating power follows the increase in carbon density, thus:

Hydrocarbons.	Percentage composition.	Illuminating power. Candles, per 5 cubic feet.
Ethane, C_2H_6	C 80 H 20	35.0
Ethylene, C_2H_4 . . .	C 85.7 H 14.3	68.5
Acetylene, C_2H_2 . . .	C 92.3 H 7.7	240.0

Series V. The Benzene Series.—About 1 to 2 per cent. of benzene, together with small quantities of toluene and xylene, are present in coal gas.

* Frankland and Thorne, Jour. Chem. Soc., xxxiii. 89. Vapour mixed with hydrogen, and tested with a slit burner.

† Foster and Dibdin, Report of Crystal Palace Electric and Gas Exhibition, 1882-83, vol. i. pp. 54–58. Vapour mixed with coal-gas, and tested with flat flame burner.

‡ G. E. Davis, Jour. Soc. Chem. Industry, 1883. ii. 519.

§ Armstrong, Jour. Soc. Chem. Industry, 1884, iii. 462.

Digitized by Google

Benzene is probably the best hydrocarbon known as an enricher of coal gas, for not only is it of very great illuminating power, but it also possesses a considerable vapour tension which enables a large quantity to be retained by the gas at low temperatures. It is therefore largely used as an enriching material.

Series VI. Naphthalene.—Coal gas usually contains traces of this hydrocarbon, which often cause much trouble by blocking up the mains and services (see p. 184).

Before dealing with the methods of using certain of these hydrocarbons for enriching coal gas, it would be well to consider the properties which are of special importance in this connection.

Vapour Tension.—Water evaporates at temperatures much below its boiling point. If water contained in a saucer be exposed to the air at ordinary temperatures it gradually disappears. Snow also evaporates even when the temperature of the surrounding atmosphere does not rise sufficiently high to melt it. Most liquids and many solids behave similarly, though the rate at which they do so varies greatly: thus ether and gasoline disappear when exposed to the atmosphere with great rapidity, but glycerine, naphthalene and mercury very slowly.

The property which bodies possess enabling them to evaporate at temperatures below their boiling point is known as their "vapour tension" or "vapour pressure."

If a few drops of water are introduced into a barometer tube in which the mercury is standing at 760 mm., and the temperature of which is 15° C., the mercury in the tube will be depressed by the water vapour formed to the extent of 12.7 mm., on raising the temperature to 30° C. the depression amounts to 31.5 mm. These figures, 12.7 mm. and 31.5 mm., therefore represent the tension of water vapour at the temperatures 15° C. and 30° C. respectively. Should the space at the top of the barometer tube occupied by the water vapour at 15° C. be equal to 1 cubic inch, then the quantity of water vapour present would be equal to $\frac{12.7}{760}$ cubic in. measured at normal pressure, whilst if the space be 1 cubic foot the quantity of water vapour would be 1728 times as much. If the barometer tube be depressed in a cylinder containing mercury until the mercury in the tube has risen to such an extent that the water vapour only occupies one half the space which it had before—the temperature remaining the same—it will be found that one half of the vapour has condensed to water, showing that it is impossible to increase the density of the vapour by compressing it. The vapour is at its maximum density for that temperature.

If the water be allowed to evaporate into a space filled with air or coal gas, or in fact any gas, instead of in the vacuous space in a barometer, the same thing happens though it takes a longer time. A vessel having a capacity of 1 cubic foot filled with coal gas saturated with water vapour at 15° C. would contain as much of the latter as if the coal gas were absent—viz., $\frac{12.7}{760}$ of 1 cubic foot. The quantity of coal gas present in the vessel at normal pressure would therefore be $\frac{760-12.7}{760}$ or $\frac{747.3}{760}$ of 1 cubic foot.

Digitized by Google

Maximum Tension of Water Vapour (REGNAULT).

Temperature.	Tension. Millimetres of Mercury.
— 10° C. or 14° F.	2.1
0 „ 32	4.6
10 „ 50	9.2
15.5 „ 60	13.5*
20 „ 68	17.4
30 „ 86	31.5
40 „ 104	54.9
50 „ 122	92.0
60 „ 140	148.8
70 „ 158	233.1
80 „ 176	354.6
90 „ 194	525.4
100 „ 212	760.0

From the above table the quantity of water vapour present in a gas which is in contact with water may be calculated. For instance, coal gas issuing from a gasholder at a temperature of 50° F. would contain $\frac{9.2 \times 100}{760}$ or 1.2 per cent. of water vapour; and if in the mains this gas be cooled to 32° F. water will be deposited, since at that temperature the gas can contain but $\frac{4.6 \times 100}{760}$ or 0.6 per cent. of water vapour.

The vapour pressures of light hydrocarbons are much greater than is the vapour pressure of water at the same temperature, and consequently much larger quantities are taken up by gases brought into contact with such liquids. And here it may be remarked that there is no gas that possesses greater power of carrying hydrocarbon vapours than others. The quantity of hydrocarbon vapour that can be retained by a gas is simply a question of temperature and pressure, carbonic acid carrying neither more nor less than hydrogen or oxygen will carry at the same temperature.

The vapour tension of benzene at various temperatures is given below:

Maximum Tension of Benzene Vapour (DR. SYDNEY YOUNG).

Temperature.	Tension. Millimetres of Mercury.
°C. °F.	
— 10 or 14	14.97
0 „ 32	26.54
10 „ 50	45.19
20 „ 68	74.13

A gas therefore would take up at 32° F. $\frac{26.54 \times 100}{760}$ or 3.5 per cent. of benzene; 16 to 17 candle coal gas contains about 1 to 1.5 per cent. of benzene; but it must not be assumed, for reasons which will be stated, that it is therefore capable of carrying an additional 2–2.5 per cent.

The pressure of the vapours contained in a gas which has been saturated by two such dissimilar liquids as benzene and water (liquids which are not

* Calculated.

Digitized by Google

miscible) is the sum of the vapour pressures of benzene and water at the temperature at which the gas was saturated.

In the case of similar liquids such as benzene and toluene—liquids which are miscible in all proportions—the case is different. The pressure of the vapours is only about the mean of the vapour pressures of these liquids.

An example will render this clear. Let it be required to find the quantity of benzene and water vapour present in a sample of hydrogen which has been brought into intimate contact with benzene and also with water at 50° F. From the tables given it is evident that the partial pressures of the vapours present will be—benzene $\frac{45.19}{760}$, water $\frac{9.2}{760}$, and therefore the partial pressure of the hydrogen will be $\frac{760-(45.19+9.2)}{760}$ or $\frac{705.61}{760}$. The composition of the mixture will consequently be—benzene 5.9 per cent., water 1.2 per cent., and hydrogen 92.9 per cent.

If, however, the hydrogen be brought into contact, at the same temperature, with a mixture of 50 per cent. benzene and 50 per cent. toluene a different state of things occurs. These two liquids act as if they were one having a vapour tension which is about the mean of those of its components.

Thus a mixture of 50 per cent. of benzene with 50 per cent. of toluene, having a vapour pressure at 10° C. of 45.2 mm. and 10.5 mm. respectively, was found to possess a combined vapour tension of only 29.5 mm. at that temperature. Hydrogen saturated at 10° C. with this mixture would have the following composition:

Benzene	3.3 per cent.
Toluene	0.6 „
Hydrogen	96.1 „

It will be seen that the presence of the toluene has reduced the quantity of benzene which can be carried by the gas by 2.6 per cent.; and at the same time the presence of the benzene has reduced the quantity of toluene which can be present from $\frac{10.5\times100}{760}$ or 1.4 per cent. to 0.6 per cent.

In the same way a mixture of 30 c.c. of commercial pentane and 30 grains of naphthalene, having a vapour pressure at 20° C. of 496 mm. and 1.6 mm. respectively, was found to have a combined tension of only 444.8 mm. It therefore follows that were hydrogen saturated with pentane vapour, afterwards saturated with the vapour of naphthalene, pentane would be deposited until the vapour tension was reduced to that of the mixed hydrocarbons.

Having regard to these results it appears clear that coal gas saturated as it leaves the condensers with a complex mixture of hydrocarbons, many of which possess a very low vapour pressure, cannot be made to carry the vapour of even light enriching hydrocarbons of high vapour pressure without depositing part of the same, together with an equivalent quantity of each of the hydrocarbons which it contains.

At the same time, however, it has been practically proved that this displacement is not attended by any serious reduction in the illuminating power of the enriched gas, since excess of the enricher having high vapour tension is added, which makes up for the displacement of hydrocarbons of low vapour tension. And it appears probable that any deposition of naphthalene would be attended by the deposition of a much larger amount of a liquid in which it was readily soluble, with consequent removal to the syphons without obstructing the passage of the gas.

From what has been said as to the maximum vapour pressure of water,

Digitized by Google

it will be readily understood that if a gas saturated with hydrocarbon vapours be compressed, part of the vapour will be deposited.

The effects of compression therefore on the luminosity of two gases of equal illuminating power would afford evidence as to their relative permanency.

Distillation and "Cracking."—Distillation is usually effected by means of three pieces of apparatus connected together—a still, a condenser and a receiver.

The liquid is placed in the still and heat applied until a temperature is reached at which the vapour pressure is equal to the pressure of the surrounding atmosphere, when the liquid boils, and the vapour rapidly passes over from the still to the receiver, being condensed in its passage through the condenser.

If pure water be distilled under an atmospheric pressure of 760 mm. all the vapour will pass from the still at a temperature of 100° C.; whilst if the pressure be reduced to 9.2 mm., the vapour pressure of water at 10° C. (see table), the water can be distilled with ebullition at 10° C.

The behaviour of a pure hydrocarbon is similar. Pure benzene under an atmospheric pressure of 760 mm. boils at a temperature of 79.9° C., which temperature remains constant until the whole of the benzene has passed from the still to the receiver, the constancy of temperature being an indication of the purity of the substance under distillation. When a mixture of hydrocarbons is distilled—for instance, a mixture of benzene and toluene—ebullition commences at that temperature at which the combined vapour tension is equal to the atmospheric pressure. As, however, the partial pressure of the benzene is much greater than that of the toluene, a larger proportion of benzene will pass over at first, and the toluene gradually accumulating in the liquid remaining in the still, the temperature of ebullition rises until at the end, when toluene alone is left, it becomes 110° C., the temperature at which the vapour pressure of toluene is equal to the atmospheric pressure. The liquid which first passes over into the receiver will thus contain the largest proportion of benzene, whilst that which passes over last may contain little or none, and the intermediate fractions will contain benzene and toluene in various proportions. The separation of benzene from toluene by such a method of distillation would therefore be practically impossible.

By the insertion, however, between the still and the condenser of a dephlegmator, the operation is rendered practicable. The dephlegmator—the Coffey still for example—is an apparatus in which the mixed vapours as they leave the still are brought into contact with portions of the condensed liquid, the effect being, that whilst a portion of the lighter vapour passes from the head of the dephlegmator into the condenser, the heavier vapours are to a great extent washed back into the still by the condensed liquids falling down the dephlegmator. This principle has been applied to an invention of great merit hereafter described—viz., the Young and Bell system of oil gas manufacture.

If heavy petroleum oil be distilled two or three times from one end to the other of a sealed glass tube bent at right angles, the constitution of the oil will be altered. The complex molecules of the oil are not even sufficiently stable for them to undergo distillation under pressure without splitting up —"cracking"—into lighter oils. This is, no doubt, what occurs at first in the making of oil gas from heavy or gas oil, the lighter oils so produced, then, by the continued action of heat, being decomposed into permanent gases and light vapours.

Tocher* has investigated the action of heat upon two pure members of

* Jour. Soc. Chem. Industry, 1894, xiii. 231.

Digitized by Google

the paraffin series—octane and decane; and his results show that these bodies are cracked into simpler liquid members of the same series, accompanied by gaseous olefines, paraffins and hydrogen. At a temperature of 500° C. ethylene and higher olefines, methane and hydrogen were produced, and at 900° C. ethylene, methane and hydrogen.

The decomposition of hexane by heat has also been investigated by Haber and Oechelhaeuser.*

Enrichment with Hydrocarbon Vapours.—This method of enrichment is a very old one, but only during the last few years has it been successfully adopted for the enrichment of gas in bulk. Success has been largely due to the invention by Messrs. Maxim and Clark of a suitable apparatus for the purpose. Fig. 191 shows the plant as arranged by the Gas Lighting Improvement Company. By means of the pump G light petroleum spirit is drawn from the tank E and forced into the carburetter J, which resembles a surface condenser, steam, however, instead of water being passed around the tubes down which the spirit falls. The heat of the steam transmitted through the tubes rapidly volatilises the spirit, the vapour of which collects at the top of the carburetter, and if the valve M be kept closed, develops sufficient pressure to stop the pump. Upon opening the valve M the vapour passes through the injector L into the main N, along which the bulk of the coal gas to be enriched is passing. A small quantity of the latter, however, is drawn through the pipe O by means of the injector, and this mixing with the vapour prevents any condensing before it is thoroughly mixed with the bulk of the gas in N. The valve M is regulated so as to pass sufficient vapour to give the enrichment required, and the operations are then automatic, if too much spirit is being pumped into the carburetter the pressure rises and checks the pump and *vice versâ*. A constant steam pressure of about 25 to 30 pounds must be maintained.

The hydrocarbon generally used is a light petroleum known as "carburine," having a specific gravity of ·680. Pure benzene or 90 per cent. benzol may, however, be used with the same apparatus, as may also the light spirit which is obtained from the residuals produced in the manufacture of oil gas, and which consists almost entirely of unsaturated hydrocarbons; benzenes, olefines, &c.

	Specific gravity.	Cubic feet of vapour per gallon of liquid.	Cubic feet of coal gas raised 1 candle power by 1 gallon.	Comparative value.
Petroleum spirit (carburine)	0.680	30	2800	1.0
Oil gas spirit . . .	0.842	38½	9300	3.3
Benzene	0.880	40	9500	3.4

In the above table, a comparison is made of the three enriching materials based upon experiments conducted at the Windsor Street Works. Given the price of the three materials, it will be a simple matter to calculate which will be the most economical.

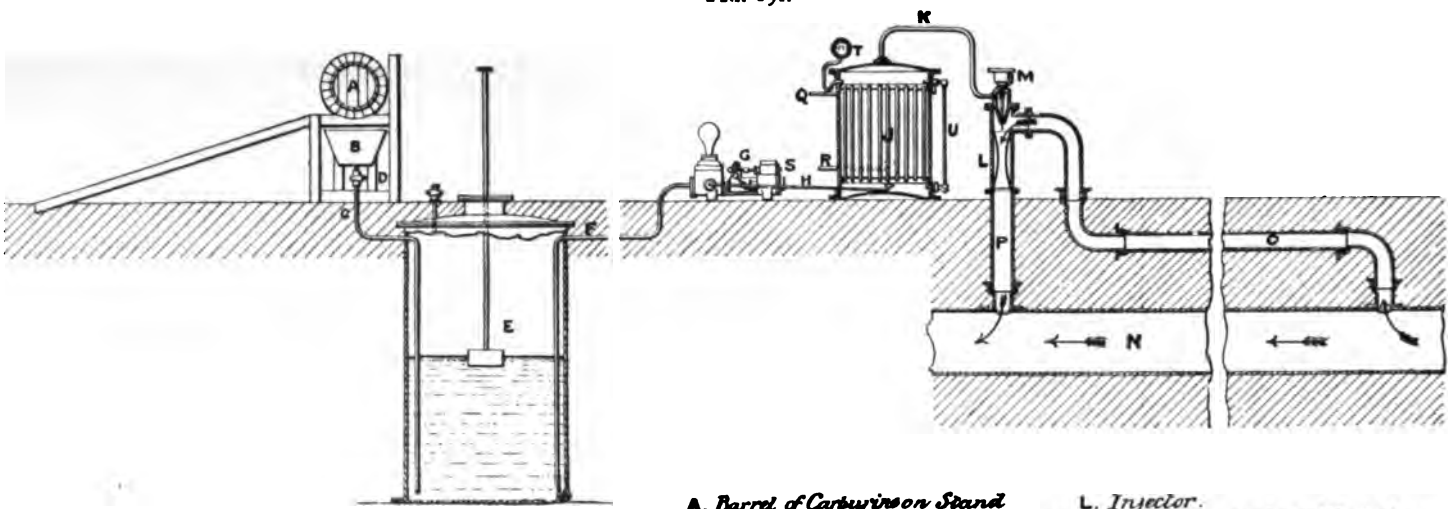
There exists a great difference of opinion as to the enriching value of the above-mentioned hydrocarbons.

Other investigators have given as the result of their experiments an enriching value for benzene varying from 1770 to 6170 candles per gallon, and for carburine as much as 3000 candles per gallon. From the figures given above it will be seen that the value of benzene as determined by the writer is 1900 candles per gallon and carburine 560 candles per gallon,

* Jour. Gas Lighting, 1897, lxix. 349.

Digitized by Google

FIG. 191.



A. Barrel of Carburine on Stand
B. Funnel (with cover) used in filling store tank
C. Pipe leading to Store tank.
D. Cock on do,
E. Store tank with float.
F. Suction pipe from Store tank to pump
G. Steam pump
H. Delivery pipe from pump to evaporator
J. Evaporator.
K. Carburine delivery pipe to Injector.
L. Injector.
M. Regulating valve with index
N. Main containing coal gas to be enriched
O. Inlet to Injector from Coal-gas main
P. Outlet from Injector (very rich gas) to gas main
Q. Steam inlet to evaporator.
R. Steam outlet blow off.
S. Steam inlet to pump.
T. Pressure gauge shewing vapour pressure
U. Water gauge shewing level of Spirit.

Maxim and Clark's Enriching Apparatus.

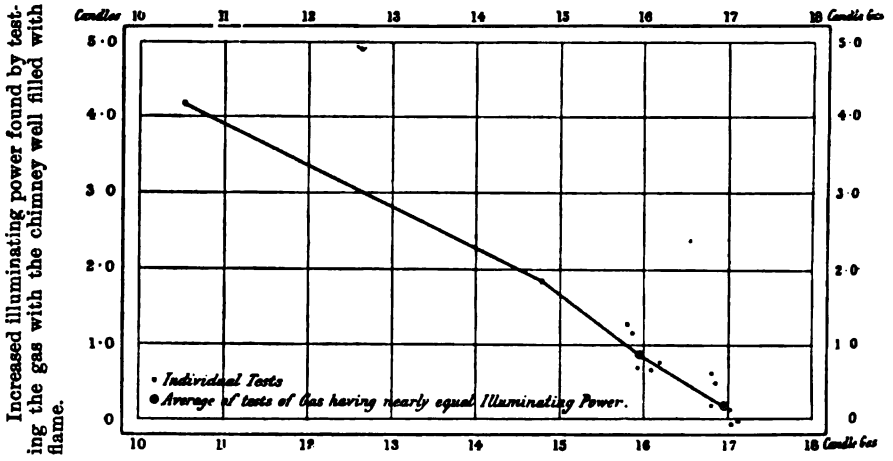
Digitized by Google

benzene possessing nearly $3\frac{1}{2}$ times the value of carburine. These values are for the enrichment of a low quality coal gas by one or two candles.

It is therefore considered necessary to explain in what way the results given in the above table were arrived at and to give the reasons for the method of procedure adopted in the photometric testing. That the differences resulted from the way in which the hydrocarbons were supplied to the unenriched gas is improbable, for experiments made by volatilising weighed quantities of the enriching material into measured quantities of poor coal gas of known illuminating power contained in an experimental holder, and also by volatilising the hydrocarbon into the stream of coal gas immediately on its way to the test burner gave results which were in close agreement.

The differences are in all probability to be accounted for by the method adopted in such investigations of determining the illuminating power of the

FIG. 192.



Illuminating power of gas found by testing at the standard rate of consumption of 5 cubic feet per hour in a chimney 6 in. by 2 in.

coal gas before and after enrichment, and it is maintained that in many investigations of this character the enriching materials have been credited with a fictitious value due to testing the unenriched gas disadvantageously as compared with the enriched gas. Thus it is no unusual thing for the coal gas before and after enrichment to be tested by the same size batswing or union jet burner, the size usually adopted being quite unfitted for testing a poor gas, though suitable for the enriched gas, and for the enricher to be credited with all the gain in illuminating power thus ascertained. This method of experimenting might be carried *ad absurdum* by using a burner for testing the unenriched and the enriched gas which was capable of properly consuming the former, when it would probably be found that the enriching material was of no value whatever.*

It has also been shown repeatedly that the standard Argand burner is quite incapable of giving the photometric value of poor gas when consumed in the usual way at the referees' standard 5 cubic feet per hour rate.

* For a consistent method of testing an enricher, reference may be made to the following papers: "The Comparative Value of Various Oils for Enriching Coal Gas," Trans. Incorp. Inst. Gas Engineers, 1892, ii. 99; and "Acetylene and its Enrichment Value," *ibid.*, 1895, v. 133.

Digitized by Google

When gas of a lower quality than about 17 candles is tested at that rate of consumption, this burner draws an excessive supply of air into the flame, and a considerable proportion of the luminosity of such a gas is destroyed.

This is well shown in the diagram (Fig. 192), from which it will be seen that a sample of coal gas which, tested at the standard rate of consumption, gave an illuminating power of about 10 candles per 5 cubic feet, when tested in such a manner as to prevent an excessive supply of air to the flame gave an illuminating power of about 14 candles per 5 cubic feet.

Tests of Gas from various Coals Carbonised at a Temperature of about 1700° Fahr.

The Methven Screen was used as a Standard of Comparison.

Series A.*	Average.	Series B.†	Observed increase in Illuminating Power.	Average increase.
Candles.	Candles.	Candles.	Candles.	Candles.
10.52	—	14.62	4.10	—
14.72	—	16.61	1.89	—
15.82		17.17	1.35	
15.83		17.04	1.21	
15.84	15.96	16.58	0.74	0.96
16.14		16.86	0.72	
16.18		16.98	0.80	
16.72		16.95	0.23	
16.80		17.34	0.54	
16.88	16.93	17.39	0.51	0.22
17.01		17.12	0.11	
17.08		17.05	— 0.03 (*a*)	
17.11		17.09	— 0.02 (*a*)	

(*a*) Decrease in illuminating power.

Yet in determining the value of an enriching material the gas, both before and after enrichment, is frequently tested at the 5 cubic feet rate.

It may be argued that as 5 cubic feet is the recognised official rate, this should be adhered to in this country even in investigations of this character, and that what one wants to know is the enrichment value of material with gas so tested. It will be evident, however, from the diagram that if this be done an enriching material when used for raising so-called 10-candle gas by one candle will be given a value of about twice as much as if it had been used to raise so-called 14-candle gas 1 candle, and of about four times as much as if it had been used to raise 17-candle gas 1 candle. When the experiments are made by means of the jet photometer the results are equally anomalous, this photometer being standardised with gas tested at the 5 cubic feet rate. It is not surprising therefore that the values given to enriching materials vary so greatly.

The enriching values given in the table were obtained by what is considered to be a consistent method of testing both the unenriched and the enriched gas by means of the Argand burner, and one by which comparative results can be obtained when the illuminating power of the gas does not exceed 18 to 19 candles—namely, by consuming the gas before and after enrichment at such a rate as to develop the maximum efficiency in each case.

* In this series the gas was tested with a No. 1 "London" Standard Argand burner, with a 6-in. by 2-in. chimney, and at the standard rate of consumption of 5 cubic feet per hour.

† In this series the same gas was tested with the same burner and chimney, but the latter well filled with flame; the indicated illuminating power being corrected to the 5 feet rate.

Digitized by Google

An example may be given which shows how easily erroneous views may be formed as to the value of certain hydrocarbons in contributing to the luminosity of coal gas. A sample of coal gas tested with the London Standard Argand was found to have an illuminating power of 17.5 candles; the same gas when tested at the 5 cubic feet rate after absorption of hydrocarbon vapours, benzene, &c., by means of heavy oil only gave an illuminating power of 4 candles. It would, however, be quite incorrect to assume, as is usually done, that the loss of luminosity due to the removal of the benzene, &c., from the gas represented 77 per cent. of the total, for when this poor gas was tested in a suitable manner—namely, by increasing the consumption to 7 cubic feet per hour, it gave an illuminating power of 17.43 candles with that consumption, which is equal to 12.45 candles per 5 cubic feet.

The real loss in luminosity due to the abstraction of hydrocarbon vapours was therefore only 29 per cent.

Enrichment with Coal Tar: The Dinsmore Process.—From time to time much effort has been directed to converting into a permanent illuminating gas the liquid hydrocarbons resulting from the carbonisation of coal, and forming a part of the constituents of coal tar. It has generally been sought to effect this by subjecting the gaseous products before condensation of the tar to the further action of heat, although some of the projects (as, for example, Eveleigh's, in 1869–71) embraced the separate conversion into gas of the liquid products. Of the illuminating value of some of these products there can be no question; and so long as coal tar continued to be, commercially, almost a valueless substance, there was every inducement to endeavour to turn it to account for enriching the gas. Accordingly, we find that as early as the year 1850 a process was patented by James Owen for converting tar into gas, by passing crude or "nascent" gas with its vapour of tar and ammonia through a long stratum of ignited charcoal or coke, thereby evolving an additional quantity of gas free from the impurities "of the said nascent gas." Following on this attempt were the processes patented at various times by Montauban, Lowe and Kirkham, Grafton, Murdoch, Michiels and others, ending with that of Eveleigh already referred to. From one cause or another—chiefly the difficulty arising from stoppages caused by the accumulation of pitchy substance in various parts of the apparatus—all these inventions were unsuccessful. Moreover, in the meantime tar increased enormously in importance, owing to the discovery of its valuable products, benzene, anthracene, &c., and their derivatives, and the consequent rise and growth of the coal tar colour industry. After a long period of quietude, influenced, in all probability, less by the apparent hopelessness of the task than by the high value which tar had reached, inventions directed to the utilising of tar for gas-making purposes were again roused into activity by a period of almost unprecedented commercial depression. In 1886–7 tar was again little better than a drug upon the market, the price having gradually fallen from the highest point—namely, upwards of 50*s.* per ton of 200 gallons—to about 7*s.* per ton and even less. At many gas-works the practice—which had long been abandoned as unprofitable—was again resorted to of burning tar in place of solid fuel to heat the retorts; and in many quarters this was strongly advocated, not only as an economical expedient, but also as a means of artificially regulating the market price. About this time attention began to be directed to a process patented by Mr. Dinsmore, and in November 1889, at a meeting of the Manchester Institution of Gas Engineers, Mr. Isaac Carr gave the following description of it as modified by himself and applied at the Widnes Gas Works.*

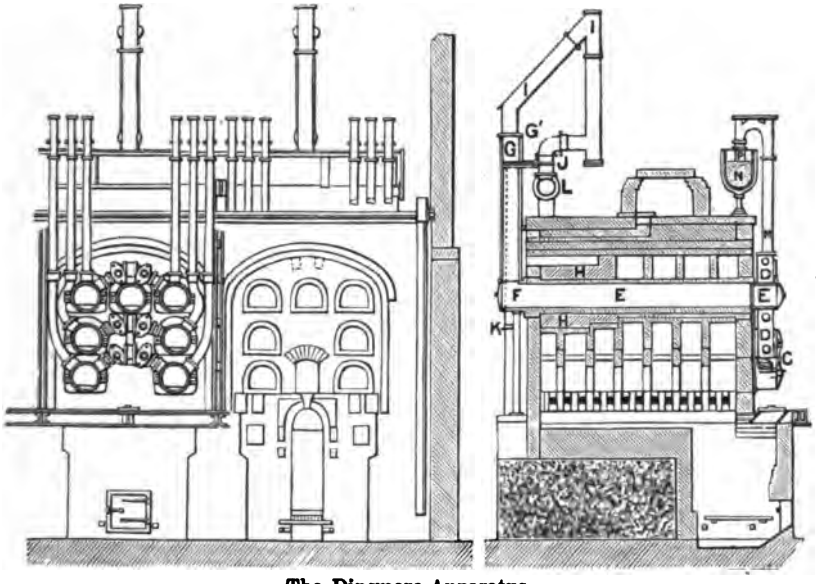
"The diagrams represent the arrangement of plant now in use at the

* Jour. of Gas Lighting, &c., 1889, liv. 1060.

Digitized by Google

Widnes Gas Works. The six retorts in each bed (Fig. 193), are charged with coal. The duration of the charges is six hours; and the work is done at hourly intervals. Supposing the process to be in operation, the whole of the taps C are open, and a heavy seal on the dip-pipes P forces the gas through, by way of the collecting chambers D, into the 'duct' E, where a portion of the tarry vapours in suspension with the gas are, by the influence of heat, fixed as permanent illuminating gas. The velocity of the gases in passing through the duct is kept fairly equal by one retort being charged each hour as just stated. The duct is of fireclay, and the regulation of the temperature therein is of importance, as on this principally depends the success or otherwise of the operation. I have so far found that the best results are obtained when the following graduations of temperature

FIG. 193. FIG. 194.



The Dinsmore Apparatus.

are, as nearly as possible, maintained:—Two-thirds the length at the inlet end from 1700° to 1800° F., or a bright cherry red, and cooled down at the outlet end to about 1200° to 1300° F., or a dull red.

"Some difficulty was experienced before such a degree of heat could be regulated and maintained in continuous working, for this secondary retort differs from the primary one, inasmuch as the latter receives the charge of coal evenly along the whole length—the workk eing thus equally distributed throughout; whereas in the former, where gases have to be dealt with, equal distribution of work with such an arrangement is not possible, as the instant the gases enter the duct they attain the same temperature, or nearly so, as the duct itself, and after travelling along a few feet, the absorption of heat by the gases is practically *nil* as compared with that at the inlet. It will therefore be clearly seen that if the duct were heated in the same way as an ordinary retort, the result would be the reverse of what is required. The outlet end, having so little work to do, would become intensely hot, and the gases would, in consequence, become attenuated. Nor is this the only loss that would arise; for, with an excessive heat, the destruction of some of the ammonia in the gas must naturally occur. It may, perhaps, be argued

Digitized by Google

by some that a shorter length of duct would better answer the purpose—that, by taking the gas out (say) half-way along, it would not be deteriorated to anything like the same degree as by passing the whole length. This idea presented itself to my mind, and I tried it; but the results were unsatisfactory, for I found that continuity of contact at a reduced temperature was absolutely necessary to ensure efficient working.

"In Fig. 194, HH show the brickwork and air channels that are applied for graduating the heat. The function of the water-jacket pipe G is to check the deposition of carbonaceous or pitchy matter which, with a plain pipe, has been found to block up solid in a few hours' time. As the expansion and contraction on the inner pipe are greater than on the outer one, an expansion joint is provided at G'. Through this pipe and the bridge-pipe I the gas passes into the foul main, which completes the operation.

"When it is required to open the duct for inspection, the taps C and the valve J are closed; the gas meanwhile passing up the ascension pipes to the hydraulic main. Each of the taps C, of course, comes separately into action at the time of charging. Before opening the retort-door the tap is closed, to prevent the back-flow of gas from the other retorts, and opened when the retort is sealed. The valve J may be actuated from the ground-floor by means of the rod and wheel K. The collecting chambers D are fitted with doors to give access for cleaning; but deposit here is slight, and requires little attention."

The following additional particulars are from another paper read by Mr. Carr before the Liverpool Section of the Society of Chemical Industry, during December of the same year*:—

"Thirty-five mouthpieces are now worked at Widnes on this system, and the gas supplied to the town consists of two-thirds ordinary gas and one-third Dinsmore gas. It is found that this mixture is quite equal to ordinary gas both as regards its permanency and travelling power, no naphthalene stoppages having been noticed. The extra cost of erecting the Dinsmore plant is £7 per mouthpiece, and the yield of gas is increased in quantity about 10 per cent. and in quality from 4 to 5 candles. The quantity of tar gasified amounts to about 4 gallons per ton of coal carbonised. By means of this process, it has been found possible to dispense with the use of cannel altogether at the Widnes works, and a mixture of 75 per cent. of Arley coal together with 25 per cent. of Arley slack, which mixture is delivered at 7*s.* 4½*d.* per ton, has been found to yield 9600 cubic feet of gas of 19-candle power per ton, one-third of the gas being carbonised by the Dinsmore process, as above stated. The mixture of coal and cannel formerly employed cost 11*s.* 9*d.* per ton, and yielded 10,600 cubic feet of gas of 18-candle power per ton. Deducting the lower value of the coke from the coal now employed (1*s.* per ton), and making due allowance for the increased cost of the plant, depreciation in value of and lower yield of tar and increased heating required for the retorts worked on the Dinsmore system (about 5 per cent.), the total saving through the adoption of this process will amount this year to £1758 13*s.*, a sum equal to 4.1*d.* per 1000 cubic feet on the quantity of gas sold. In this estimate no account is taken of the increased illuminating power of the gas (from 18 to 19 candles), which can be put down at least at £528. The following statement (p. 215) gives full details as regards the relative costs of the Dinsmore and the ordinary process of gas-making:—

"The Dinsmore process is not applied to the whole of the retorts in use in order to allow of the regulation of a proper proportion between the quantity and illuminating power of the gas and the quantity of the residual products.

* Jour. Soc. Chem. Ind., 1889, viii. 960.

Digitized by Google

Statement showing the Working by the Ordinary Process only.

		£	s.	d.
Coal, 8,981 tons, or 85 per cent., at 11*s.*		4,939	11	0
Cannel, 1,585 „ 15 „ „ 16*s.*		1,268	0	0
10,566				
Average per ton, 11*s.* 9*d.*		6,207	11	0
To balance		9,990	9	0
		16,198	0	0

This mixture will give 18-candle gas.

		£	s.	d.
Gas produced, at 10,600 cubic feet per ton = 112,000,000 cubic feet at 2*s.*		11,200	0	0
Coke produced, 10,566 tons coal × 8.247 cwts. coke = 4,356 tons coke, at 11*s.*		2,395	16	0
Tar produced, 10,566 tons coal × 12.27 galls. tar = 636 „ tar, „ 29*s.*		922	4	0
Sulphate of ammonia 140 „ „ £12		1,680	0	0
		16,198	0	0

Statement showing the Working with two-thirds Ordinary and one-third Dinsmore Process.

		£	s.	d.
Coal, 11,653 tons; average per ton, 7*s.* 4½*d.*		4,297	0	11
Dinsmore, 37,300,000 cubic feet, at 10,300 cubic feet per ton = 3,621 tons coal				
Ordinary, 74,700,000 „ 9,300 „ = 8,032 „				
Extra cost of carbonising 1,087 tons, at 2*s.* 3*d.*		122	5	9
Five per cent. interest on additional capital outlay, £245		12	5	0
		4,431	11	8
To balance		11,749	2	0
		16,180	13	8

This mixture will give 19-candle gas.

		£	s.	d.
Gas produced, at 9,611 cubic feet per ton = 112,000,000 cubic feet at 2*s.*		11,200	0	0
Coke produced, 11,653 tons coal × 8.247 cwts. coke = 4,805 coke, less 5 per cent. on one-third = 74 = 4,731 tons, at 10*s.*		2,365	10	0
Tar (ordinary), 8,032 × 11.27 tons coal galls. tar = 445 tons, at 29*s.*		645	5	0
„ (Dinsmore), 3,621 × 7. 0 = 124 „ „ 19*s.* 8*d.*		121	18	8
Sulphate of ammonia = 154 „ „ £12		1,848	0	0
		16,180	13	8

1*s.* per ton on 10,566 tons, the value of raising quality from 18 to 19 candles, £528 6*s.*

	£	s.	d.
To balance by ordinary process	9,990	9	0
„ one-third Dinsmore process	11,749	2	0
Balance in favour of the Dinsmore process	1,758	13	0

Digitized by Google

"The cost of labour is somewhat less, the yield of ammonia slightly greater than when gas is made in the ordinary way.

"The following table, giving the composition of pure Dinsmore gas, compared with that of one-third Dinsmore gas, is taken from a report on the process by Mr. William Foster, M.A. :—

Table giving the Chemical Composition of Samples of Gas manufactured at the Widnes Gas Works by the Dinsmore Process.

(All quantities are expressed in volumes per 100 volumes.)

Description of Gas.	Crude Dinsmore gas, made Nov. 12, 1889. Lighting value by "G" Argand, after purification, 21.8 candles: sp. gr. .424 (dry air = 1).	Purified Dinsmore gas, taken from experimental holder Nov. 11, 1889 (gas made the previous day). Illuminating power 22.3 candles; sp. gr. .428.	Town gas, made Nov. 11, 1889. Illuminating power 18.66 candles (one-third is Dinsmore gas); sp. gr. .420.
	Volumes per 100 vols. of gas.	Volumes per 100 vols. of gas.	Volumes per 100 vols. of gas.
Carbonic acid gas (CO_2)	2.75 This includes H_2S After purification.	0.23	2.09
Heavy hydrocarbons	5.30	6.76	4.37
Carbonic oxide (CO)	7.78	8.10	8.44
Marsh gas (CH_4)	40.24	40.34	33.39
Free hydrogen	46.06	43.98	51.16
„ nitrogen	0.60	0.59	1.10
	99.98	100.00	100.55
Carbon density, heavy hydrocarbons	2.85	2.96	3.7 (?)
Hydrogen density, heavy hydrocarbons	6.08	5.80	6.3
Volumes of oxygen used per 100 vols. of gas	130.6	136.5	120.3
Volumes of carbonic acid produced per 100 vols. of gas	63.12	68.44	58.7

"The illuminating value of the Dinsmore gas and also its specific gravity is given in the following table, drawn up by Mr. Foster :—

Table giving the Specific Gravity and Illuminating Value of Dinsmore Gas.

(The candle power is reduced to standard temperature and pressure.)

Date.	Specific gravity of gas; dry air taken as unity.	Illuminating power of gas in sperm candles.	
		Burner used, "G" Argand.	Burner used, No. 4 flat flame.
1889.		Consumption, 5 cub. ft. per hour.	Consumption, 5 cub. ft. per hour.
November 9	—	21.00	—
„ 9	.435	21.72	—
„ 10	.431	21.00	—
„ 10	.436	22.40	20.70
„ 10	.428	—	—
„ 11	.428	22.30	—
„ 11	.419	21.27	19.28
„ 12	—	21.00	—
„ 12	.424	21.80	20.00

Digitized by Google

"As regards the tar obtained by the Dinsmore process of carbonisation, it was found to contain 10.3 per cent. of water and 3.6 per cent. of light oils, whilst the tar as supplied from the works, where gas consisting of one-third Dinsmore gas was furnished, contains 4.1 per cent. water and 6.2 per cent. light oils. Mr. Foster states that there is no doubt that the increased illuminating power of the gas produced in this process is in a great measure due to the rendering of some of the more volatile portions of the tar permanently gaseous, but he does not attribute it entirely to this."

With regard to the comparative statements prepared by Mr. Carr, showing the results of the ordinary and the Dinsmore processes, it is to be observed that credit is given to the latter for the whole of the pecuniary advantage resulting from the substitution of inferior material. It not unfrequently happens in the case of gas-works that are situated not far distant from coal-fields that economy results from the use of the cheapest material that can be procured, such as slack, or smudge, which does not find so ready a sale at a distance from the colliery as the large or screened coal. The lower cost at which this can be procured often much more than compensates for the increased cost for labour, wear, tear, &c., which its use entails. In the same way, it is not unlikely that Mr. Carr might have found economy from the use of his cheaper material with the ordinary process, although necessarily, in order to maintain the same illuminating power, a smaller yield per ton must have resulted. Compared with such use, with all its attendant disadvantages, if any, the value of the Dinsmore process might have been more convincingly determined. Moreover, the Dinsmore gas when tested for illuminating power, was free from carbonic acid, having been passed through lime, whereas the gas made by the ordinary process, with which the comparison was made, was not so purified, being freed from sulphuretted hydrogen only. This would count for something in the production of increased luminosity. These and the selection of the burner are points which require to be fully borne in mind when estimating the commercial advantages of the process, but whatever these may ultimately prove to be, it is at all events certain, not alone from the statements of Mr. Carr, but from the testimony also of independent observers such as Professor Foster and others, that a distinct success has been achieved in the establishment of a process for the economical conversion of coal tar into a permanent illuminating gas. This success is, in the opinion of Professor Watson Smith,* wholly attributable to the modification of the original process introduced by Isaac Carr. Of these modifications the water-jacketed ascension pipe is rather a prominent feature, and Watson Smith says of it that it "looks like a daring adventure, but it is really very ingenious, and scientifically correct." It may not be without interest to mention that a water-jacketed ascension pipe, for use with the ordinary process, and as a cure for stoppages in the ascension pipes, formed the subject of a patent which was taken out by the author in 1885.

In the paper just referred to, after giving the results of his analyses of the "surplus Dinsmore tar" and of ordinary tar (one-third Dinsmore), from which it appears that the Dinsmore tar contains a smaller quantity of "light oils," but is richer in anthracene oil than ordinary tar, Watson Smith says:—

"Proceeding now to the chemical changes taking place in the Dinsmore duct, let us ask, 'What are the results of a prolonged red-heat on the vaporised products of the gas retort?' The direction, it may be replied, is one and the same in all cases, with but few exceptions—namely, to the decomposition or resolution of the more complex hydrocarbons or carbon compounds into less complex and more simple forms, the extreme limits

* "The Chemistry of the Dinsmore Process," Jour. of Soc. Chem. Ind., 1890, ix. 445.

Digitized by Google

being carbon (soot, coke), carbonic oxide and hydrogen. This final ideal stage is never fully reached, of course, and yet to some extent and in some degree it is, for the products named are always present, and increase with increased heats; and there are some carbon compounds more easy of such ultimate resolution than others. The paraffins may suffer resolution and yield olefines and hydrogen, and these again may be further reduced to acetylene and hydrogen. Mr. Francis Jones found in the Dinsmore gas about 0.14 per cent. of acetylene, and he adds that the acetylene in the gas of the Manchester Corporation does not exceed 0.05 per cent. Acetylene being an illuminating constituent, this is a point favourable to the Dinsmore gas; but whilst no doubt its greater quantity is due to the prolonged heat in the duct, yet it may also be due in part to the class of coal carbonised. But let us once more regard the acetylene which Francis Jones finds present to an extent nearly three times that usual in ordinary gas. Berthelot has shown that when heated in a glass tube to dull redness, it is converted into benzene, $3C_2H_2 = C_6H_6$. It also plays an important part in the formation of toluene, the xylenes, and probably of anthracene. Now when we regard the tar analyses we observe the diminution of the phenols in the Dinsmore tar, besides that of the first light oils containing the benzenes. Let us now ask, what becomes of the phenols which have vanished from the Dinsmore tar? Experiment has proved that phenols may be reduced, either alone, to form the corresponding hydrocarbons, or in conjunction with certain non-saturated hydrocarbons to form aromatic hydrocarbons of more complex types. The Dinsmore duct we may consider as a red-hot tube lined with carbon in a finely divided, or at all events porous, form, and the crude gas itself, as it comes from the retorts, as filled with a vapour of finely divided carbon or sooty particles. The duct thus serves to prolong the contact of the red-hot carbon with the constituents of the gas. I have proved by actual experiment that when pure carbolic acid vapours are passed through a red-hot glass tube containing iron turnings, or carbon, the result is the same, namely, reduction to benzene is effected, according to the equation $C_6H_5.OH + C = CO + C_6H_6$.

"In fact, this is the most convenient way I know for preparing pure benzene free from thiophen for lecture experiments, and I have long used it. Cresol in like manner yields toluene. I have also tried the experiment of passing a mixture of carbolic acid vapour and carbonic oxide through a red-hot tube with pumice-stone, and I found scarcely any action to take place, whilst with a mixture of hydrogen gas and carbolic acid or cresol, reduction takes place at a high temperature with formation as with carbon, of benzene or toluene, as the case might be. Tervet has shown that the last gaseous products yielded by the almost exhausted fuel in a gas retort, consist of nearly pure hydrogen. He patented a process for increasing the yield of ammonia from the coal being carbonised in the gas retorts. He proposed to turn the final products of a finishing retort consisting mainly of hydrogen into a retort which had been charged and working for about an hour, and thus by supplying hydrogen at the right period, he claimed an increased production of ammonia; and, indeed, he proved by experiment that this increase is an undoubted reality. If, then, the retorts in the Dinsmore process are worked consecutively through the duct, we should have along with the usual average gas from one retort, the finishing gas of the other retort (if two were working through one duct). The hydrogen at the high temperature would then certainly reduce phenols to great advantage. I am informed that the retorts are thus worked consecutively. Again, crude phenol (phenol and cresol) may contribute to form anthracene. Köhler has proved this. Probably in this reaction two molecules of cresol and one of phenol interact:—

Digitized by Google

$$C_6H_4\left\{\begin{matrix}CH_2\\OH\end{matrix}\right. + \left.\begin{matrix}CH_2\\OH\end{matrix}\right\} C_6H_4 + C_6H_5.OH =$$

$$C_6H_4\left\{\begin{matrix}CH\\|\\CH\end{matrix}\right\} C_6H_4 + C_6H_6 + 3H_2O.$$

"Finally, it will be observed that an essential difference between the ordinary gas process and the Dinsmore process is that in the ordinary case we have each retort acting independently and discharging independently its issues into the hydraulic main, where, of course, no further chemical change in the gases can be expected to occur; but in the Dinsmore process we have the final issues (hydrogen) of one retort mingling in a red-hot pipe with the earlier issues of a neighbouring retort, and we have now seen that under the circumstances interaction may take place. The latter slightly or non-luminous constituents of the finishing retort thus enrich themselves and become carburetted."

This process has been adopted at the Longwood, Darwen, Huyton and Roby, and other works. At the last-mentioned works Mr. T. Pritchard, the manager, has adopted a duct which is in the form of a diaphragm retort, made of iron, and placed outside the setting and heated by the waste heat of the setting. This arrangement affords room in the setting for an extra retort for carbonising. The waste heat is brought from the front and passes out at the back. The diaphragm causes the gas to travel from the front to the back, and then forward again; giving about twice the distance for it to travel through the duct which it would have in an ordinary single setting.

Oil Gas.—As already mentioned (Chap. 1) illuminating gas made from oil and other similar materials has been in use from about the time of the introduction of coal gas. In the year 1815 Mr. John Taylor took out a patent for producing "inflammable air or olefiant gas applicable to the purposes of giving light" from vegetable or animal oil, fat, bitumen, or resin. The apparatus employed consisted of two vertical pipes or retorts, made of metal or other material which will resist fire. These pipes were heated to redness, and the animal, vegetable, or other matter in a fluid state was allowed to trickle down the first one, in which it was converted into permanent gas and vapour, the latter being converted into gas when ascending the second pipe, through which it passed on the way to the gasholder. The unconverted residue from the oil was collected in a chamber below with which both pipes communicated.

In the years immediately succeeding the date of this invention, oil gas was a competitor with coal gas for public favour, and companies for its supply were established in various parts of the kingdom, notably in Liverpool, Edinburgh and Leith, the price charged being from 40*s.* to 50*s.* per 1000 cubic feet.

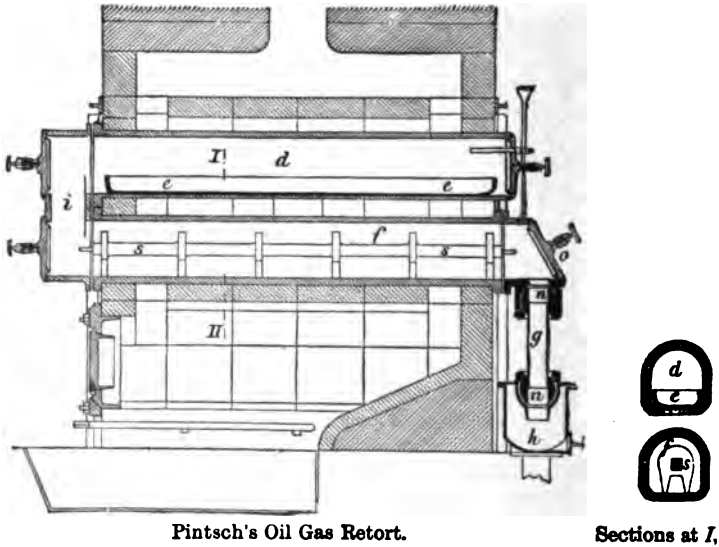
Oil gas compressed by a method patented by Gordon and Heard in 1819 was supplied by a company having the title of the "London Portable Gas Company." It was contained in vessels having a capacity of 2 cubic feet, which represented about 60 cubic feet of the gas under the ordinary pressure of the atmosphere. These vessels were delivered in carts to the premises of consumers, and returned when empty to be refilled. On being compressed a fluid was deposited from the gas which could be drawn off in the liquid state, and it was in this liquid that Faraday discovered a new hydrocarbon which is now known as benzene.

The popularity of oil gas at this time was of but brief duration. In 1824 parliamentary powers were sought for the establishment in London of works for its manufacture to compete with the coal gas supplied by the Chartered

Digitized by Google

and other companies. These offered the strongest opposition to the application, which, however, was supported by some of the most eminent scientific men of the day, amongst whom were Sir Humphry Davy, Michael Faraday, T. W. Brande, and Sir W. Congreve. On its behalf was urged, amongst other things, its superior illuminating power as compared with coal gas, and therefore the smaller quantity of it required to give the same lighting effect, resulting in a saving of capital outlay upon manufacturing and distributing plant. Also its freedom from impurities, the smaller amount of heat evolved for equal light as compared with coal gas, and the comparative simplicity and cleanliness of its manufacture. On the other side it was contended that coal gas could be rendered equally free from impurities, and that, light for light, it could be supplied to the consumer at a very much cheaper rate than oil gas. After a very protracted inquiry the

FIG. 195.



Pintsch's Oil Gas Retort. Sections at *I*, *II*.

Bill was thrown out, and about the same time the manufacture of oil gas was in several places discontinued in favour of the more economical one of coal gas.

At this period oil was costing about 3*s*. per gallon; it now, owing to the development of the shale oil industry in Scotland and the discovery of vast stores of petroleum in America and also in Russia, costs only about as many pence.

The second era of oil gas may be said to have commenced with the invention of Mr. Julius Pintsch in 1873, since which time there ha e been a series of inventions, the main object of which, as regards this country, is the application of oil gas to the lighting of railway and other carriages, ships, floating buoys, lighthouses, and other isolated buildings.

The chief apparatus employed for this purpose, those of Pintsch, Pope, Keith and Patterson, are referred to in Vol. II. of this work. The first-named of these is shown in Fig. 195. It consists of two cast-iron D retorts set one above the other, the size of each retort being about 6 feet long, 10 inches wide and 9¾ inches deep. The oil is run into the upper retort through a syphon, falling upon an iron tray *e e* which fits loosely in the retort *d*. The vapours are passed through the neck *i* into the second or

Digitized by Google

lower retort *f*, which may be partly filled with firebrick or a series of baffle plates *s s*. The retorts are heated to a cherry red. The gas leaves the lower retort in the form of a dense yellow vapour, which passes downwards through *g* into the hydraulic main containing water, where a large portion of the tar is deposited. It then passes to a condenser, where the remainder of the tar is separated. It is necessary to watch very carefully not only the heat of the retort, which must be kept uniform, but also the tar produced in order to ascertain if the proper quantity of oil is being supplied. Should the tar contain any oil a drop placed upon a piece of white paper will appear greasy, and the supply of oil to the retort must be checked or the heat increased. Usually, however, the colour of the gas, which should be yellow, is regarded as a safe guide. On leaving the condenser the gas is

FIG. 196.

Mansfield's Oil Gas Producer.

passed through a washer containing water, which practically completes the process of purifying. It is stated that each pair of retorts as described will produce gas at the rate of about 2500 cubic feet per 24 hours.

An earlier invention than the foregoing is that of Mansfield, who took out a patent in 1847 for an oil gas producer consisting of a cast-iron cylinder placed vertically and lined with firebrick. Into this cylinder is inserted a cast-iron retort having an outlet pipe at top connected with an hydraulic seal pot placed on the same level as the bottom of the cylinder. This retort hangs by a flange on the cast-iron cover, for the convenience of removing when necessary. The oil is caused to flow through a syphon pipe into the retort, where it is converted into gas. Before any oil is admitted the brick lining is heated and the retort brought to a cherry-red heat by a fire underneath, combustion being carefully adjusted by means of a damper at the top of the furnace. Fig. 196 shows this apparatus as constructed and used at the present time. It is fully described in "Gas and Petroleum Engines," by Professor Wm. Robinson (E. & F. N. Spon).

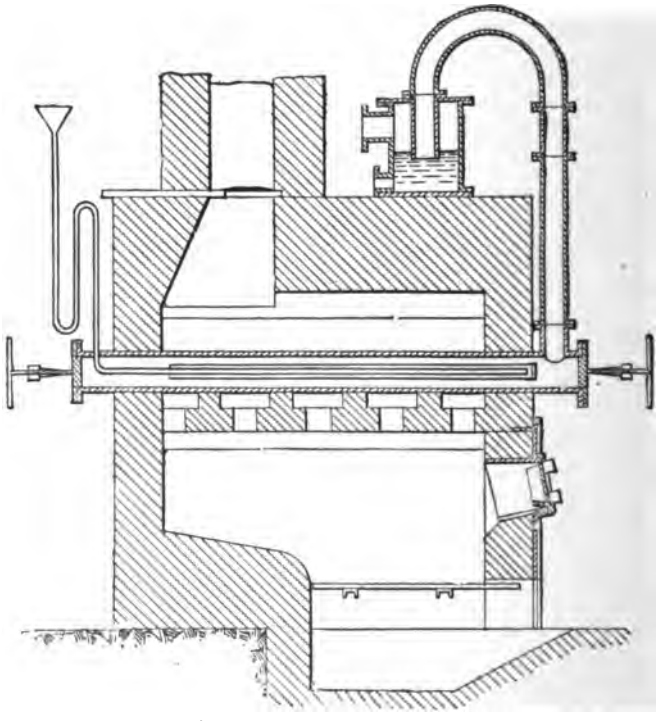
The Patterson apparatus (Fig. 197) consists of a horizontal retort, circular in form, and set in a furnace in the same way as a gas retort, only with a slight incline towards the gas outlet end. The retort need not be more than

Digitized by Google

about 6 inches diameter and from 7 feet to 8 feet long. The oil flows along the bottom, or it may be made to travel first through a small wrought-iron pipe extending to the gas outlet end and returning to the oil inlet end. A retort of this description is capable of converting into gas from 1 to 1½ gallons per hour, which, allowing for stoppages, would be equivalent to a production of about 2200 cubic feet of gas per 24 hours.

Very similar results are obtained by all these processes. It is necessary that the oil used should be fairly free from carbonaceous matter, otherwise stoppages in the retort and ascension pipe would be of too frequent occurrence. A very suitable oil is that which is known as "intermediate," produced in the distillation of shale. It has a specific gravity of about

FIG. 197.



Patterson's Oil Gas Retort.

0.840 and yields nearly 90 cubic feet of about 60 candle gas per gallon. Except, however, in Scotland, where it is produced, this oil is more costly than American or Russian oil.

The residue obtained from this manufacture consists of 20–30 per cent. of tar, the lighter portions of which when separated are suitable for enriching coal gas by means of a carburetter. Dr. Dvorkovitz has shown that by converting the oil at a low temperature in retorts or tubes of small diameter so as to increase the heated surface with which the oil vapour is brought into contact, the formation of benzene is greatly promoted.

The influence of temperature is shown by the following results of experiments made under the directions of the Author.*

* Trans. Incorpd. Inst. Gas Engs., 1892, ii. 98

Digitized by Google

Russian oil, "Lustre" Sp. gr. 0.826—candles per gallon	1177° F 272.8	1410° F. 739.0	—	1592° F. 585.4
Russian "Solar Distillate" Sp. gr. 0.865—candles per gallon	—	1380° F. 672.0	1445° F. 799.2	1690° F. 529.2
Scotch "Shale" Sp. gr. 0.854—candles per gallon	—	—	1447° F. 837.8	1630° F. 769.4

As the oil was supplied to the retort at a constant rate—1 gallon per hour—the figures are comparable, and it will be seen that at temperatures *above* as well as *below* a certain temperature, varying with the nature of the oil, a reduction in the illuminating value of the gas obtained takes place.*

The results were obtained with a Patterson retort without interior tubes. Further experience has proved that by the insertion of tubes the quantity of carbon deposited in the retort may be materially lessened, and also that by careful attention to the rate of oil supply in accordance with the temperature of the retort, practically the same results, 950 to 1000 candles per gallon, may be obtained from both light and heavy Russian oils, and also from shale oil.

As will be apparent from what has been said above, considerable attention is required in order to maintain good results. If from inattention the heat of the retort is too great, or, which amounts to nearly the same thing, the oil supply is insufficient, carbon is deposited in the retort and ascension pipe, and gas of poor quality is obtained; whilst if the heat be low, or oil supply excessive, considerable quantities of tar are formed, which is little more than a waste product, and the quantity of gas obtained is much diminished.

With every care, however, these apparatus leave much to be desired. As all the oils necessarily used consist of complex mixtures of hydrocarbons of varying boiling points and differing degrees of resistance to the action of heat, an operation in which they are all subjected to the same temperature and length of exposure cannot but be imperfect. A temperature and length of exposure which is sufficient to convert into gas to the best advantage some of the hydrocarbons contained in an oil will be insufficient or too great for others.

All these defects are to a great extent overcome in the scientific invention of Messrs. Young and Bell, which although but of recent introduction is already used to a considerable extent as an auxiliary to coal gas plant more particularly where gas of a high quality is required. Fig. 198 shows the arrangement of plant employed. The retorts are of cast iron, about 9 feet long and 27 inches in diameter, and are inclined so that the back is about half the diameter lower than the front. They are set in a furnace back to back with a setting of coal gas retorts, the waste heat from which is sufficient to maintain the low temperature necessary for the decomposition of the oil. With "blue oil," which is a product of the distillation of shale, having a specific gravity of 0.885, it has been found that the most suitable temperature is from 1200° to 1300° F. at the exterior of the retort, and from 900° to 930° F. in the interior. This is much lower than is found necessary with the other methods of distillation previously described.

When the retorts are heated to the required temperature, and the scrubber *N* and hydraulic main *E* charged with oil, the regulating valve *K* is opened, and oil allowed to flow through the syphon pipe *K* into the standpipe *D*, so as to fill the inclined bottom of the retort. The rate at which the oil is allowed to flow into the retort depends very much upon the nature of the oil, and the percentage of carbon which it contains. It should,

* This observation was afterwards confirmed by Prof. V. B. Lewes, Jour. Soc. Chem. Industry, xi. 584, 1892.

Digitized by Google

however, flow at such a rate that only a part of it is converted into permanent gas immediately, the remainder being but partially decomposed, leaving the retort in the form of vapour. This vapour becoming liquid in the hydraulic main, condenser, and scrubber, returns to the hydraulic main, passing thence into a settling tank *F*, from the bottom of which any solid matter in the oil may be drawn off. Into this tank a supply of fresh oil, equivalent to that which is being permanently made into gas, is automatically admitted, and the mixture of fresh and condensed oil is fed into the retort. The permanent gas continues onward from the scrubber through a station meter to the inlet of the coal gas purifiers.

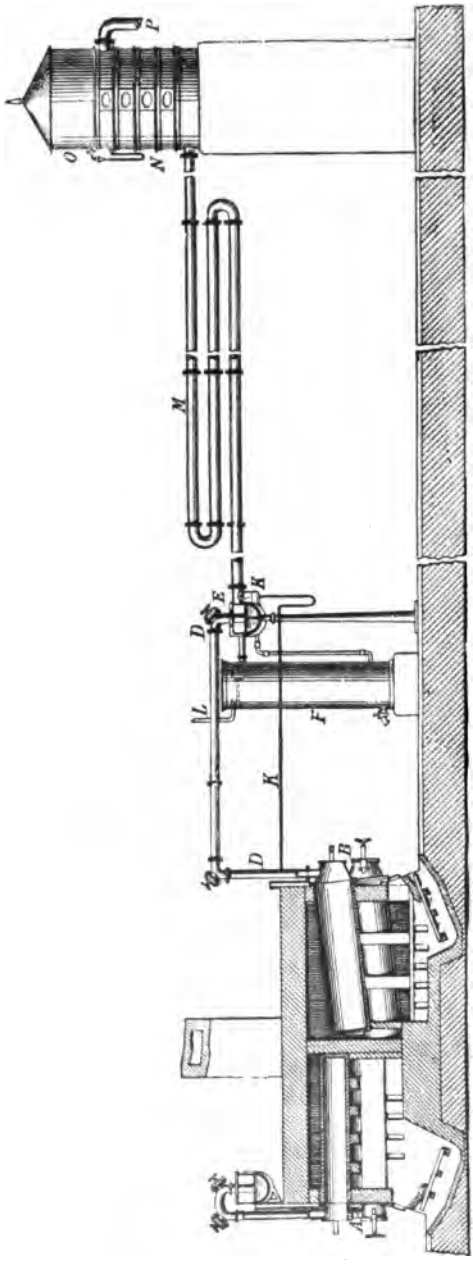


FIG. 198. Young and Bell's Oil Gas Apparatus.

"Thus," says Mr. Bell,* "the oil which is introduced into the apparatus, after serving as a washing agent to remove the condensable matter from the out-flowing gas, finds its way into the retorts where it is partially decomposed, and the resulting products, as they pass upwards through the apparatus, are simultaneously subjected to gradual cooling and condensing, and to the washing action of the down-flowing oil. By this means the permanently gaseous part only of the products, which has withstood the action of the final washing with the fresh oil that is periodically pumped into the scrubber, is allowed to pass away, while the condensable part is returned to the retort, and is again and again subjected to this process of alternate decomposition and condensation and scrubbing, with the result that the original oil is completely

* Transactions of North British Association of Gas Managers, 1893, p. 41.

Digitized by Google

split up into permanently gaseous compounds and solid carbon, the latter of which is left in the retort in a hard and dry condition."

This separation of the oil into gaseous and solid products is a distinguishing feature of the invention; and it is of advantage, inasmuch as not only is the oil converted into gas to the fullest extent, but the residual product is a useful and saleable article instead of being, as in other processes, rather a source of embarrassment than otherwise. When a sufficient accumulation of solid matter has taken place within the retort the flow of oil is stopped for a short time, when the mass becomes converted into coke of excellent quality, practically free from sulphur, and containing only a very small percentage of ash.

According to Mr. S. Glover,* with retorts having a superficial area inside of 46 square feet, and heated to the proper temperature, 118 gallons of oil can be made into gas per retort per 24 hours, producing upwards of 10,000 cubic feet of gas, the illuminating power of which would be about 90 candles. He also states that the cost per 1000 cubic feet of oil gas, manufactured by this process when working on a small scale, and using only 1 ton of oil per day, has been found to be as follows:

	£	s.	d.
One ton of oil at works	3	7	6
Royalty	0	2	6
Labour	0	3	0
Fuel	0	5	0
	3	18	0
Less value of coke per ton	0	5	0
	3	13	0

This for a production of 22,000 cubic feet per ton of oil is equal to 40*d.* per 1000 cubic feet nearly.

And he thus sums up the merits of the process.

1. The plant is an exceedingly simple one, and can be erected at a small cost and successfully worked by the ordinary workmen of a gasworks.

2. It produces a permanent gas of great value as an enriching agent, while the gas being quickly and easily made, ready means are afforded of controlling the illuminating power, and the actual work done by each gallon of oil used can be accurately ascertained.

3. The range of oils suitable for gas-making by this process is greatly increased; the crudest oil can be completely resolved into gas and good hard coke.

4. The enriching gases produced are mixed with the gas to be enriched in such a way that the highest duty is obtained from both the coal gas and the enriching gas.

5. Enrichment is provided at such a cost as to enable companies and corporations to supply a high candle-power gas as cheap as, if not cheaper than, per unit of light, it is usually done by a low quality of gas.

Professor Lewes† states that the difference which exists in chemical composition between oil gas made by the various processes is, after all, but slight. The Young process, however, owing to the slightly lower temperature which is employed, gives a gas which is richer in unsaturated hydrocarbons, which are of greater value as enrichers than saturated hydrocarbons, and which consist chiefly of ethylene and butylene. The averages of many analyses of gases are compressed in the following table:

* Trans. Incorpd. Inst. Gas Engs., 1894, iv., 152.
† Cantor Lecture, Society of Arts, delivered December 7. 1896.

Digitized by Google

	Young.	Paterson.	Pintsch.
Unsaturated hydrocarbons . . .	43.83	33.16	35.65
Saturated hydrocarbons	36.30	45.15	45.37
Hydrogen	16.85	19.65	12.44
Carbon dioxide	0.63	0.50	0.74
Carbon monoxide	0.00	0.50	0.60
Oxygen	1.14	0.60	2.00
Nitrogen	1.25	0.44	3.20
	100.00	100.00	100.00

Carburetted Water Gas.—Gas of so rich a quality as that which is produced from oil, and having an illuminating power of 80 or 90 candles, is unsuitable for general consumption, owing to the difficulty attending its economical combustion. It has been proposed to mix oxygen with it so as to secure more complete luminous combustion than is possible with the existing types of burners; but the idea has not met with favour. Moreover, as has been observed by Mr. J. Stelfox, "a large power of enrichment by the use of retorts making a small quantity of 90-candle gas would not do much to help the gasmaker through a week of darkness and scarcity of gas. At such times a large volume of gas is the one thing needful."

This "one thing needful" is supplied by what is commonly known as "water gas," which, when made luminous by a mixture of oil gas, is now, under the name of "carburetted water gas," very largely used in America, and already, to a considerable extent in this country, as a substitute for, or an auxiliary to, coal gas.

Ever since the discovery of the compound nature of water by Cavendish and Lavoisier towards the close of the last century, invention has been active in the endeavour to turn it to useful account by the production of a cheap combustible gas, and during one period alone, namely, from 1824 to 1858, no fewer than sixty patents were taken out for this object, numerous schemes being devised for combining with it the distillation of rich hydrocarbons, so as to form illuminating gas capable of being placed in competition with that which is produced solely from coal. One of the most prominent of these, known as "White's hydrocarbon process," introduced in 1847, was actually employed for a time for lighting several towns of more or less importance. It consisted in producing from "steam in contact with fuel and strips of iron, at a very high temperature, a mixed gas of hydrogen and carbonic oxide," which was afterwards mixed with gas made from "oil or fat or tar, so as to produce a compound gas fitted for illumination." The following advantages were stated by Sir Edward Frankland in 1857 to be derived from the process:

"1. The production of gas from a given weight of common coal, or of cannel, is increased by 46 to 290 per cent., according to the quality of the material employed.

"2. The luminous power is increased by 12 to 108 per cent., the more when coals are employed which produce gas of a highly luminous character.

"3. The quality of residual tar is lowered, a part of it being converted into gas of a strong, luminous power."

When using boghead cannel, producing by itself about 13.500 cubic feet of gas per ton, from 52,000 to 75,000 cubic feet of 12-candle gas per ton could, it was stated, be produced by this process. The steam was decom-

Digitized by Google

posed in cast-iron retorts, the excessive wear and tear of which was one of the principal causes which led to the ultimate abandonment of the process.

In the year 1846 J. P. Gillard obtained hydrogen by injecting steam into a retort or cupola containing incandescent carbon. He is stated to have obtained by this means pure hydrogen, but this is, of course, impossible. The gas produced by his method was used for lighting in conjunction with what is described as a platinum basket or wire cage surmounting an argand burner, the basket or cage being heated to incandescence by the combustion of the gas. This system, which accurately foreshadowed the modern system of incandescent gas lighting, was for several years subsequent to 1856 employed for lighting the streets of Narbonne, having been previously in use at Passy.

In the later applications of his process Gillard appears to have substituted a vertical cupola for horizontal retorts, as White had also done; but the economy which was thereby effected did not prove sufficient to secure permanence for it.

The failures to produce "water gas" economically had hitherto been so complete that the idea almost came to be looked upon as chimerical. Interest, however, in the subject was revived in this country by the process of Mr. R. P. Spice, who employed six cast-iron retorts set vertically in a furnace, which was fired with breeze. The retorts were also filled with breeze and clinkers. Steam was introduced at the upper end of the retort by a pipe extending nearly to the bottom, so that it was caused to return upward through the material within the retort. For carburetting the gas thus produced light petroleum spirit was employed, which left a residue after use having a specific gravity of about 0·690. The cost of the process was said to compare favourably with that of coal gas, but the price of coal was then very high, and with a reduction of it disappeared all chance of success for the "new gas," as it was called.

In America the high prices which have ruled there for coal gas, and the abundant and cheap supply of natural oil, have for many years combined to render it a particularly favourable field for the employment of carburetted water gas. It is, therefore, not surprising that American invention should have outstripped that of other nations in this direction, and that so large a proportion as from one-half to two-thirds of the illuminating gas now used in America should be carburetted water gas.

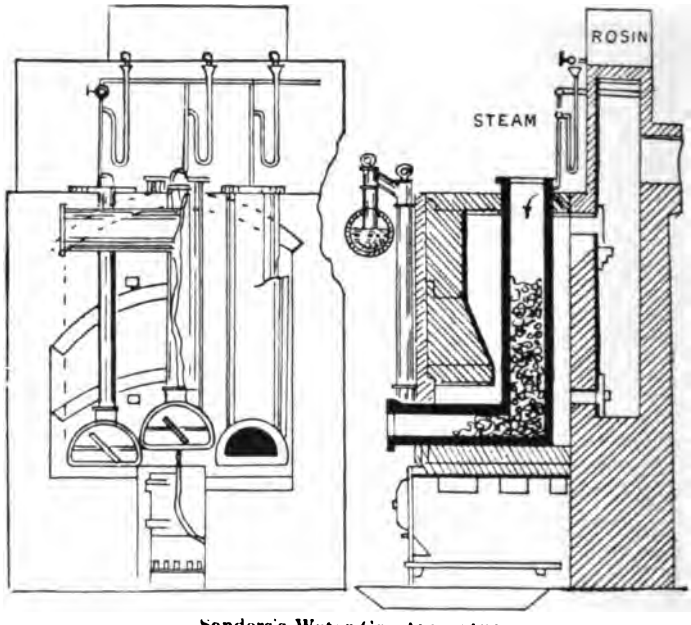
A paper read by Mr. Shelton at the meeting of the American Gas Light Association in 1889 gives the number of different forms of apparatus that had been devised and put into operation during the thirty-one years prior to that date as twenty-four, and since then twenty-five more have been added. Of these, however, only a very few are now in use, the great majority of them being but steps in the development of what is now a fairly economical process.

A principal feature in this development seems to have been the adoption of the internally fired generator, and separate superheater or carburetter for cracking the oil. In nearly all the early installations, retorts, sometimes resembling coal gas retorts, but occasionally cylindrical vessels set vertically, or a combination of the two (as shown in Fig. 199, which represents the Water Gas Apparatus of J. M. Sanders, dating from 1858), were employed either for generating or carburetting, or for both operations, either separate or combined. The cost of working retorts, and the wear and tear to which they were subject, proved a great difficulty, in addition to which their use for carburetting necessitated an additional furnace, which involved a considerable expenditure of fuel. In at least one apparatus, however, the Edgerton (Fig. 200), the waste heat from the generators was used to heat the retorts—vertical in this instance—to the required temperature. Oil gas

Digitized by Google

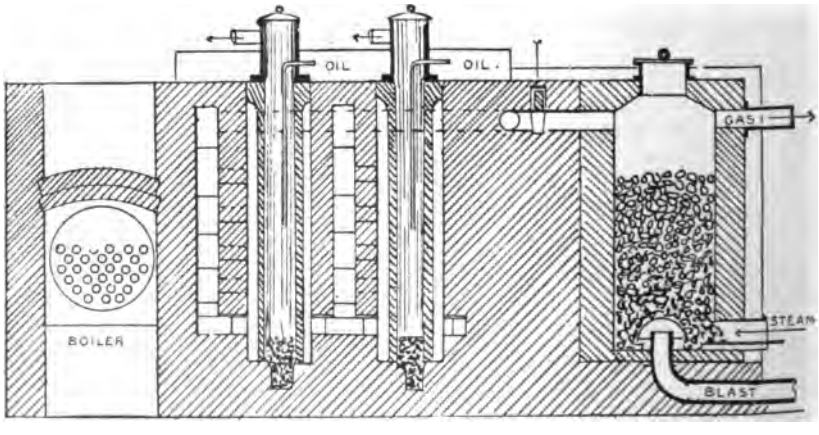
and water gas were here separately made and drawn by exhausters through meters and mixed in definite proportions; but keeping the two operations apart does not seem to have been attended with success.

FIG. 199.



Sanders's Water Gas Apparatus.

FIG. 200.



The Edgerton Water Gas Apparatus.

The first internally-fired generator of which there is any distinct record was the invention in 1831 of an English engineer, Mr. George Lowe, engineer to the then Chartered Gas Company. This was worked by natural draught, and when the coke which it contained had become sufficiently heated, steam was admitted, the resultant gas being afterwards carburetted.

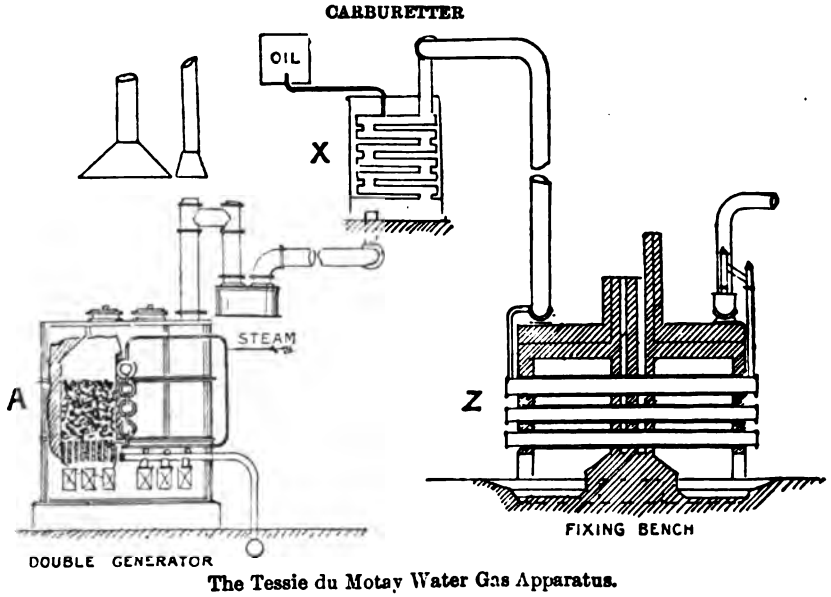
Digitized by Google

This was followed many years afterwards by an almost similar apparatus called by its inventor, M. Tessie du Motay, a "gasogene," which, however, was worked by forced instead of natural draught. The modern generator does not differ in any material respect from these early types.

The generator processes for the manufacture of carburetted water gas are divided by Mr. Shelton into two sections—namely (1) those in which a non-luminous water gas is first made, and afterwards carburetted, usually in a second apparatus by means of a second fire and a second operation; and (2) those in which water gas is made, carburetted and fixed entirely in one operation, with one apparatus and one fire, and usually through the medium of a "superheater."

1. To the first section, of which it is the most typical, belongs the Tessie

FIG. 201.



The Tessie du Motay Water Gas Apparatus.

du Motay apparatus, as modified from the original. In Fig. 201 A is the "gasogene," or simple generator, consisting of the usual firebrick-lined shell, with coal bed, grate, air blast, and steam inlets. When the fuel in the generator has been brought to the proper heat by "blowing up," the air blast is stopped, and steam admitted beneath the grate, the gas resulting from its decomposition passing into the "hydrogen holder," whence it is brought to the carburetter X. This consists of a series of shallow trays or pans supplied with naphtha, which is vaporised by steam heat. The gas containing naphtha vapour in suspension is then caused to pass through the retorts Z, where the vapour becomes converted into fixed or permanent gas. The carburetted gas then passes into the purifiers.

In this process no use is made of the waste heat from the generator.

The Wilkinson apparatus (Fig. 202) belongs to the same section. From a description of it by the inventor the following is extracted :—

It consists of a cupola (No. 1) of boiler plate lined with firebrick, having a mouthpiece at the top fitted with a gas-tight lid for the introduction of coal, doors at the bottom for the removal of ashes, an air-pipe and valves for the air blast, a steam-pipe at the top and bottom, and a gas take-off at the top and

Digitized by Google

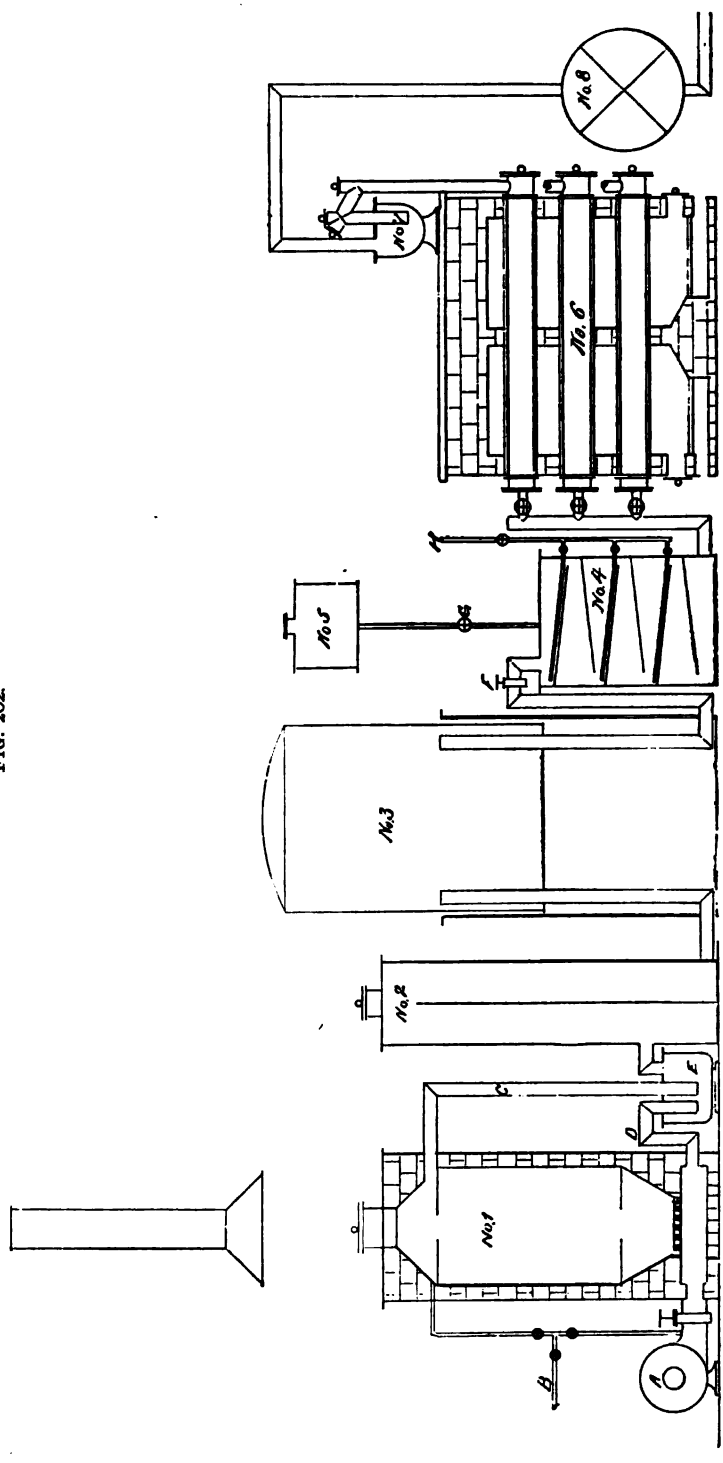


FIG. 202.

The Wilkinson Water Gas Apparatus.

Digitized by Google

bottom. It is distinguished from the ordinary cupolas used for making water gas in having the steam-pipes so arranged that steam can be let in at either the bottom or the top, the gas outlet being made reversible to correspond. This enables "down" runs to be occasionally made, by which the heat of the fuel is better under control, the apparatus is less liable to injury, and an increased production of gas is secured. The cupola should not be less than 12 feet in height, so as to have not less than 8 feet of coal for the steam to pass through. The gas after passing through the hydraulic seal *E* and scrubber (No 2) enters a governing or relief holder (No. 3) by the aid of which a steady and uniform flow is ensured to the next apparatus, known as the illuminator (No. 4). This consists of a rectangular wrought-iron vessel having inclined shelves placed one above the other, one end and the sides of each shelf being riveted to the body of the vessel. At the lower edge of each shelf, a gas way is left, so that the gas and oil vapours have to pass alternately from one end of the vessel to the other. On these shelves are placed steam coils. The water gas enters at *F*, and the oil from the overhead tank (No. 5); the oil coming into contact with the hot coils is vaporised and mingles with the water gas. Only light oil, *i.e.*, naphtha boiling at a low temperature, can be used in this apparatus, it being necessary that the oil should be completely vaporised before the bottom of the illuminator is reached.

The mixed water gas and oil vapour are now passed to the retorts (No. 6), which are of the kind known as "throughs," being open at both ends. One or more of these retorts are placed in settings resembling those of coal gas retorts, and are maintained at a uniform temperature, a bright red heat, at the take-off end, by regulating the flow of gas through them. The presence of the water gas is stated to prevent the formation of lamp-black or heavy oil, and the oil vapour is converted into permanent gas. The naphtha contributes from 35 to 40 per cent. of the volume of carburetted water gas made, 4½ gallons per 1000 cubic feet being sufficient for 30-candle gas.

From the retorts the gas passes to the hydraulic main (No. 7); it is then cooled on the way to the exhauster, whence it passes to the scrubber, and on to the purifiers.

In the event of its being desired to use oil of high specific gravity or high boiling point, the illuminator is dispensed with and the oil is introduced direct into the retorts by means of a 3-inch tube which extends two-thirds of the way through each retort from the hottest or take-off end. The object of this is to evaporate the oil before it comes in contact with the water gas, which enters at the other end. The vapour of the heavy oil then undergoes decomposition in the presence of the water gas, and a permanent illuminating gas is produced.

Crude Canadian and Russian oils can be utilised in this way with good effect, a bench of six through retorts yielding about 300,000 cubic feet per day, or a little more than half that which may be produced from naphtha of 70° B. by the aid of the illuminator to first evaporate the oil.

About 65,000 cubic feet of purified water gas per ton of anthracite coal is stated to be produced by this process; and this, by the use of about 4½ gallons of oil per 1000 cubic feet, would be increased to about 100,000 cubic feet.

It is claimed for this process, as also for that of Tessie du Motay, that as regards the finished product it is a continuous one, the regulating holder ensuring a steady and uniform flow of water gas through the illuminator and other apparatus. The waste heat, however, from the cupola is not utilised for any purpose.

2. To the second section of generator processes for the manufacture of

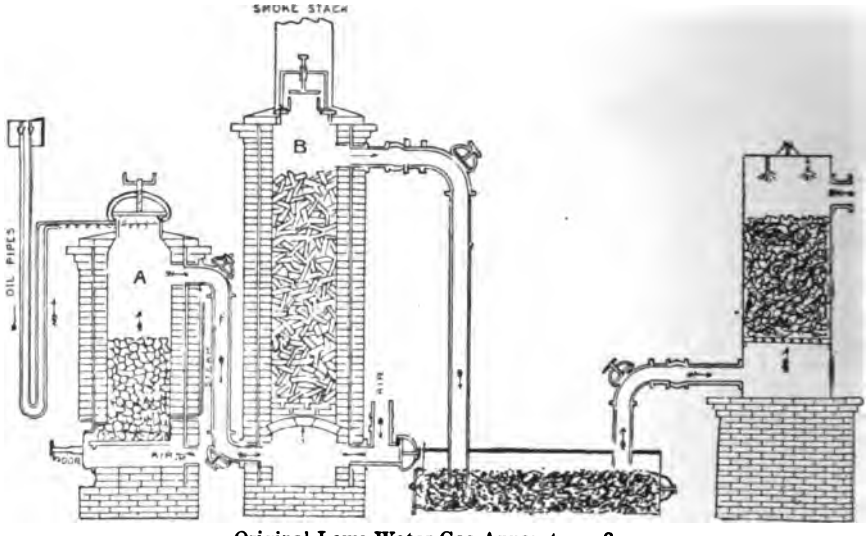
Digitized by Google

carburetted water gas, in which water gas is "made, carburetted, and fixed entirely in one operation, with one apparatus and one fire, and usually through the medium of a superheater," belong most of the apparatus in present use, both in America and this country.

This section had its origin in the invention of Professor T. S. C. Lowe, an American expert, who, in 1872 and 1875, took out patents which form the commencement of the modern water gas apparatus.

The original "Lowe" apparatus (Fig. 203) consisted of two principal parts, namely, the generator A, into which the oil was admitted, and the superheater B, filled with fire brick, in which the gas produced from the oil became "fixed" and incorporated with the water gas. Afterwards a third part was added and interposed between the generator and superheater. This vessel was called the carburetter, and the oil was admitted

FIG. 203.



Original Lowe Water Gas Apparatus, 1874.

into it instead of into the generator, being previously heated by passing it through a coil placed in the take-off pipe from the superheater. In the "Granger" modification of the Lowe apparatus (Fig. 204), the single superheater is, however, retained, and in order to get rid of the descending goose-necked pipe *f*, Fig. 203, which connects the generator with the superheater, the former is placed on a lower level, so that its outlet pipe may correspond with the bottom of the superheater. This plan is also followed in the Granger Collins apparatus.

In the Springer apparatus (Fig. 205, p. 234) the superheater is placed immediately over the generator in the same cylinder, the oil being injected above the fuel in the generator.

Fig. 206 shows an improved Lowe apparatus as used at the Beckton Gas Works, which is thus described by Mr. Thomas Goulden.* "This,"—the Lowe apparatus—"in its improved form, is built in three shells placed in a line, containing the generator in which non-illuminating water gas is made, the carburetter in which the oil used for carburetting the water gas is vaporised and partly 'fixed,' and in which the oil gas mixes with the water

* Trans. Incorpd. Inst. Gas Engs., 1891, vol. i., 67.

Digitized by Google

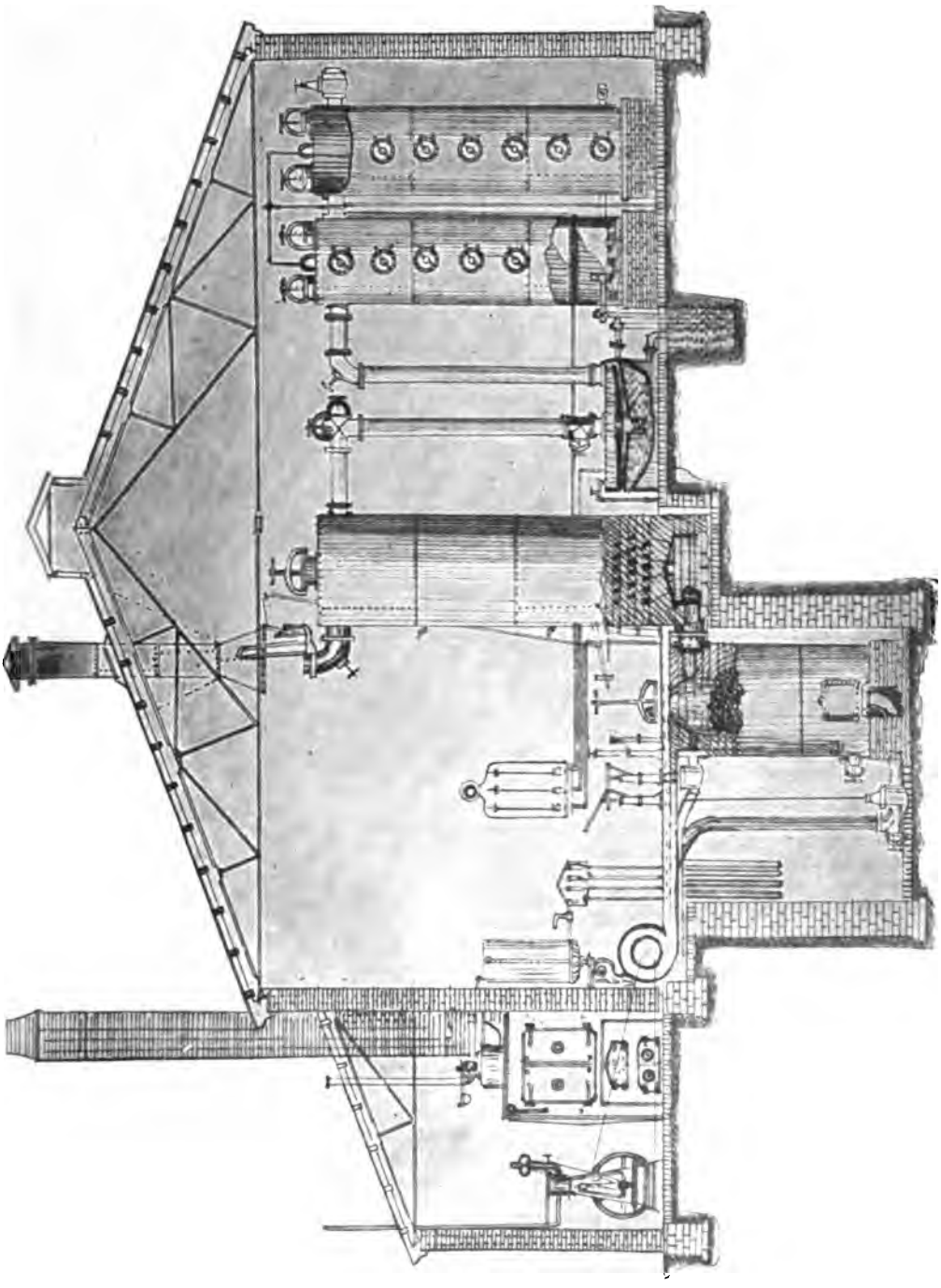


FIG. 204.

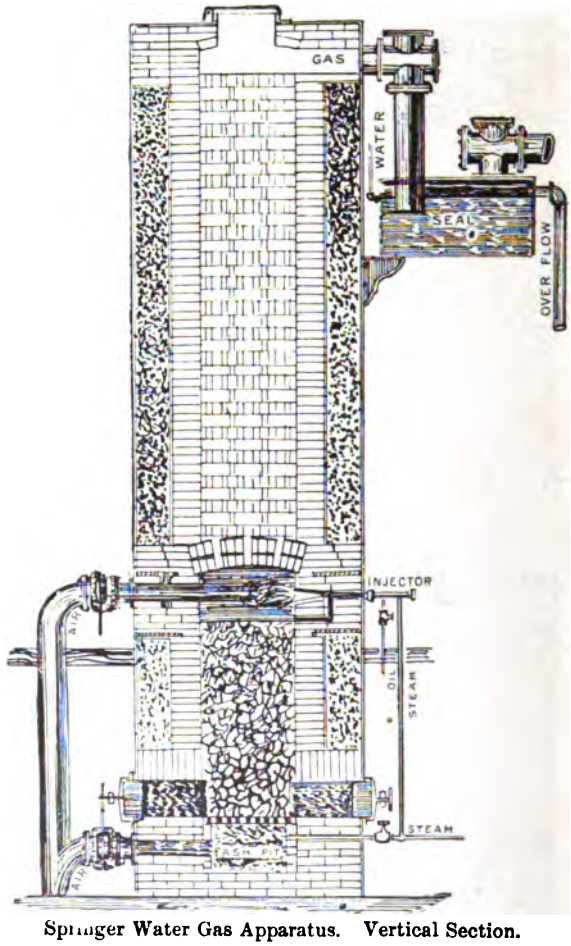
Lowe Water Gas Apparatus with Granger's Improvements.

Digitized by Google

gas, the mixture of which then passes through the third vessel, the superheater, in which the gas is finally fixed.

"The shells are lined with fireclay blocks (the carburetter and superheater are of a diameter of 5 feet inside, and the generator 6 feet 6 inches diameter), an annular space of about 2 inches, packed with asbestos or similar non-conducting material, being left between the outer surface of the blocks and the inside of the shells.

FIG. 205.



Springer Water Gas Apparatus. Vertical Section.

"The carburetter and superheater are filled with chequer bricks, about 1½ or 2 inches apart, set in tiers, the bricks in each tier being set at right angles to those in the one immediately below it. The practice is sometimes to set the brickwork in the carburetter so as to have continuous cores from top to bottom, but the Beckton plant has the carburetters fitted with tiers arranged as the bricks in the superheater are invariably set—viz., with the bricks so placed that the spaces between one tier baffle those of the next tier but one below it, thus thoroughly breaking up the flow of gases passing through the vessels.

Digitized by Google

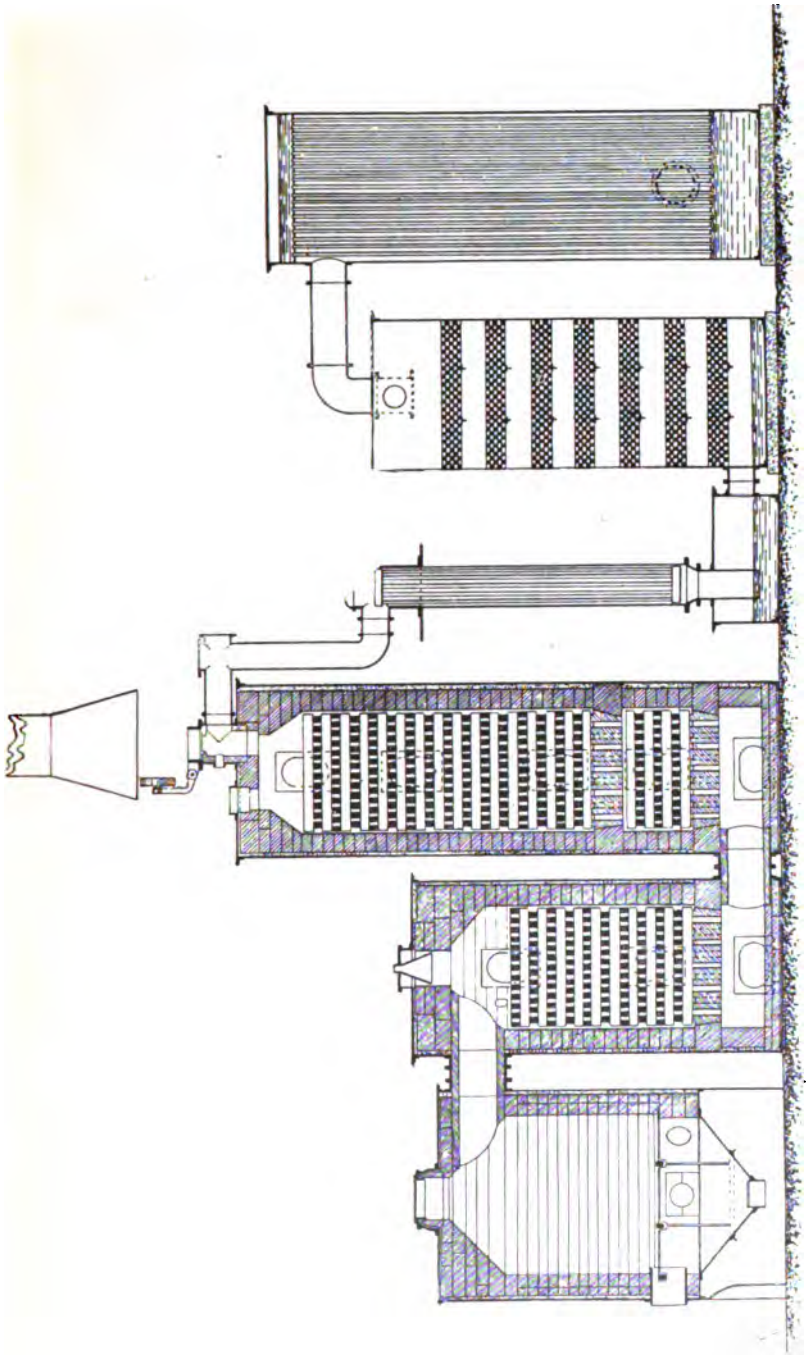


FIG. 206.

Improved Lowe Water Gas Apparatus as used at Beckton.

Digitized by Google

"The generator is fitted with a feeding door at the top. Round its circumference, immediately below the grate bars, which are supported on an iron frame, are four clinkering doors, spaced equally round the shell, through which the clinkers are withdrawn and the fire cleaned. Below the grate is riveted an inverted wrought-iron cone, the neck being fitted with a gas-tight valve, by which, when opened, the ashes escape from the apparatus.

"The generator is, near its top, connected with the carburetter by a fire-clay lined cast-iron tube, this in its turn similarly communicating at the bottom with the superheater. At the top of the superheater is an outlet, which is fitted with a stack valve, by which the waste blast gases escape from the apparatus when "blowing up," as the process of heating up the fuel and superheating apparatus, preparatory to making gas, is termed. This valve, like all the other valves required to be handled in making gas, is manipulated from the "working floor," fixed at about 14 feet from the ground line.

"The outlet pipe on the superheater is carried downwards into a cylindrical hydraulic seal-box, and forms a jacket for a series of tubes connected by a cast-iron annulus at the top and bottom; an oil heater, in fact, in which the gas being generated in the apparatus heats up the oil previous to its entry into the carburetter through a spray connected with a regulating arrangement fitted to the top cover.

On leaving the seal-box the gas is scrubbed and condensed by suitable apparatus coupled up to a relief gasholder, in the outlet of which is fixed an exhauster, by means of which the gas is forced through the purifiers.

The heating of the apparatus to the necessary temperature is effected by an air blast furnished by a Sturtevant blower, worked by a 20 h.p. engine, running at about 300 revolutions per minute. The primary air is brought into the generator under the grate bars by a branch off the main duct, the secondary air entering the top of the carburetter and the bottom of the superheater by similar smaller branches.

The admission of air to the different vessels by these branches is controlled in each case by a valve handled from the "working floor." A relief valve is fitted in each of these pipes. The admission of steam under the generator grate bars is also regulated from the floor, and it may be noted that it is important that the steam should be well spread over the area of the generator fire.

The supply of oil to the apparatus is effected from a measuring tank by means of a small steam pump which forces it through the oil heater and thence through the sprayer into the carburetter.

Fig. 207 shows a complete arrangement of this plant, with condensers, blower, and exhauster. Another form of the Lowe apparatus, as improved by Messrs. Merrifield, Westcott and Pearson of Toronto, which is somewhat extensively used, is shown in Fig. 208, in which *A* is the generator, which is oval in shape and provided with steam inlets at the top and bottom (1,1), air blasts at 2, 2, and gas outlets also at the top and bottom (3, 3). The charging stage is about 12 feet above the ground line and level with the top of the generator, which is provided with two doors (4) through which the coke is fed from a buggy holding about 8 cwts. The bottom of the generator is a grate formed with 2 inch square wrought-iron bars, having $1\frac{3}{4}$ inch spaces between them. The clinker from the fuel collects upon the grate and is removed at intervals.

B is the carburetter, or superheater, as the inventors prefer to call it. This is also oval in shape, to admit of the construction of a flue (6) connecting the top and bottom gas outlets of generator. It is placed at right angles to the latter, *C*, the fixing chamber, being a continuation of it, but cylindrical in shape. The wrought-iron casing of both is lined with firebrick, and the

Digitized by Google

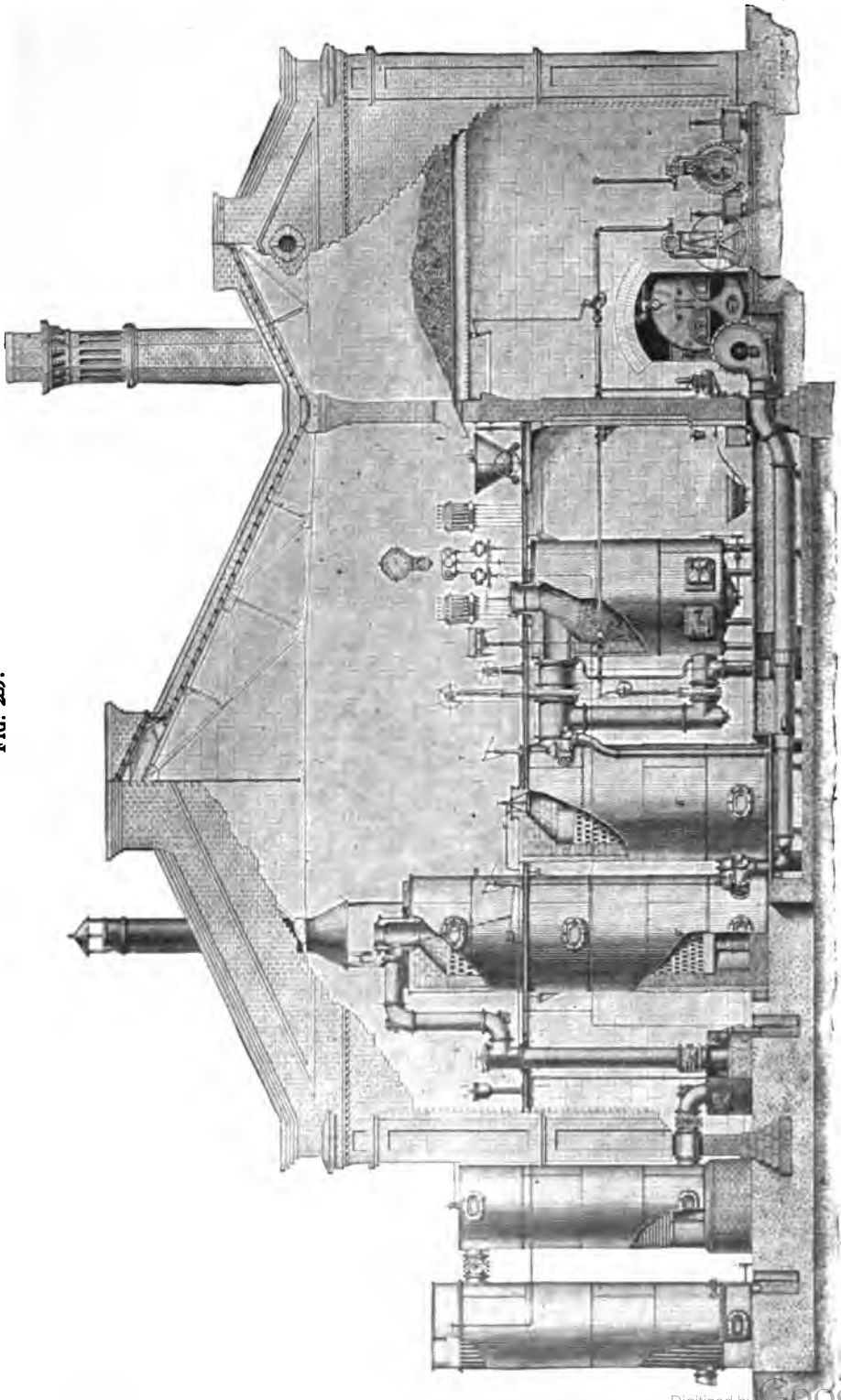


FIG. 207.

Complete Arrangement of Lowe's Improved Apparatus as used at Beckton.

Digitized by Google

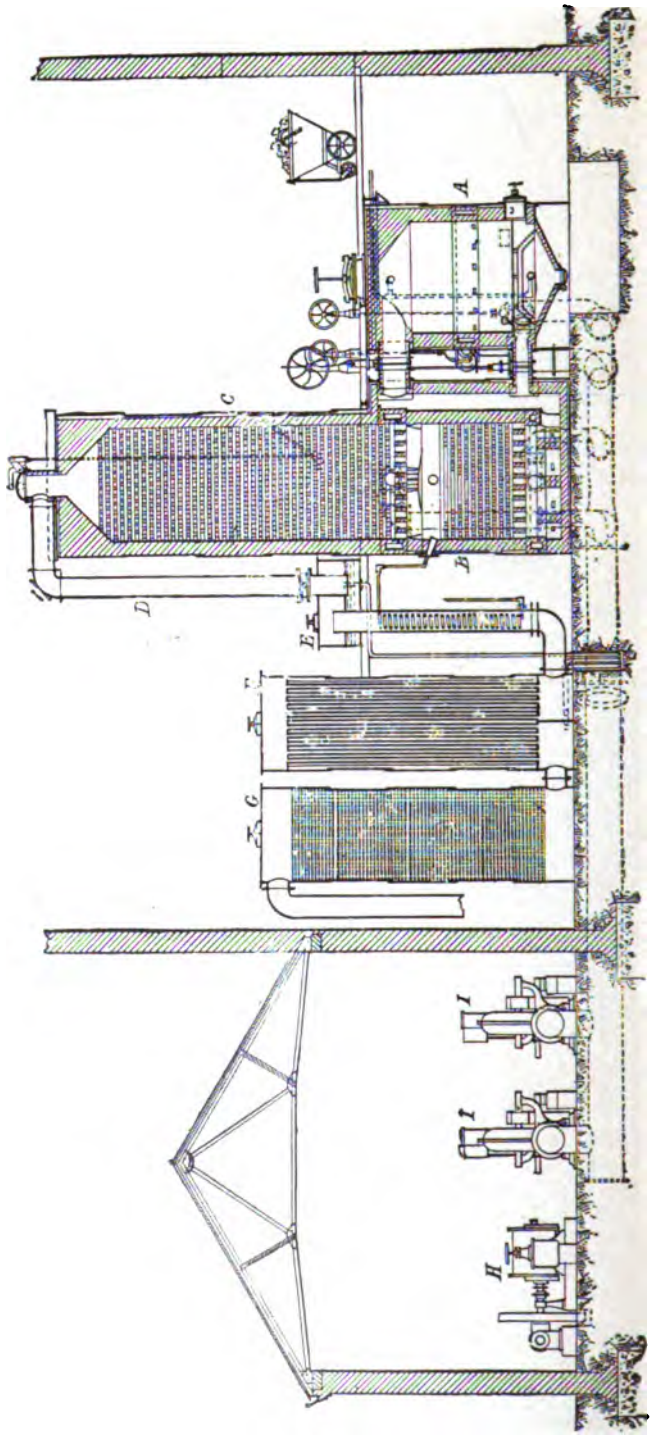


FIG. 208.

The Merrifield-Westcott-Pearson Water Gas Apparatus.

Digitized by Google

interior, almost from top to bottom, is filled with chequered firebrick work. Oil is admitted under a pressure of about 40 lbs. to the superheater at 7, 7, 7. At the very top of the fixing chamber is an outlet (8) for the waste gases, controlled by a door which is actuated from below by the lever 9; and another outlet (10) for the finished carburetted water gas.

The mode of operation is much the same in both plants. When the generator has been filled up and the coke ignited, air is blown in at the bottom inlet. This raises the mass of coke to a glowing heat, and the products of combustion, passing into the superheater, up through the fixing chamber, and away at the outlet 8, heat the interior mass of brickwork to the required temperature, which is a dull red. Air is at the same time admitted into the superheater at 11 for the combustion, when necessary, of any carbonic oxide that would otherwise be allowed to pass off unconsumed.

When the apparatus is first started the operation of heating up can be performed in two or three hours, after which it (or the "blow" as it is called) occupies from three to five minutes. At the end of this time what is called the "run" is commenced. The air is shut off from both generator and superheater, and steam turned through the former at the bottom, oil being at the same time turned on to the superheater. The steam in contact with the incandescent carbon being decomposed, hydrogen gas is given off, and the oxygen uniting with the carbon forms carbonic acid and carbonic oxide, the former being capable of conversion into carbonic oxide also by further contact with incandescent carbon. "Water gas" is therefore a mixture of hydrogen and carbonic oxide, together with a percentage of carbonic acid, varying according to the completeness of the operation, the object being to produce as little of the last as possible, so as to save cost in coke and also in purification. The "run" occupies from six to nine minutes according to circumstances. The operation, therefore, consists of alternate "blows" and "runs"; "blows" in which the fuel and apparatus are heated up, and "runs" in which the heat thus generated and stored is utilised for the production and carburetting of water gas. Occasionally, what is called a down run is made for the purpose of heating the fuel at the bottom of the generator, steam being admitted at the top, instead of at the bottom of the latter.

The oil entering the superheater in the form of a spray becomes vaporised, and the vapour passing through the apparatus becomes for the most part fixed or converted into permanent gas, mixing with and carburetting the water gas.

On leaving the fixing chamber the now carburetted water gas, which is at a high temperature, passes down the standpipe *D* into the cylindrical vessel *E*, in which a hydraulic seal is formed by causing the standpipe to dip a few inches into water maintained at a constant level. The object of this seal, like that of the dip pipe used in the manufacture of coal gas, is to prevent the gas under any circumstances from passing back to the fixing chamber. It also cools the gas to some extent and removes a portion of the tarry matter, the remainder of which is separated in the condenser and scrubber. The latter is filled with trays or grids made of wood, and piled one above another, the object of which is to remove by friction any tarry matter that may have escaped separation in the condensers.

The products of condensation, tar, light oil and water, flow by gravitation into an underground tank where the water gradually separates.

As gas making by this system is intermittent, it is necessary to compensate for this and secure continuous action of the purifiers by the provision of a gasholder which, from its function, is called a "relief" holder. Sometimes —and this is the best arrangement, because it tends to uniformity of quality of the gas at the outlet—the whole of the gas as made is caused to enter the holder, whence it is drawn by the exhauster and forced onward through the

Digitized by Google

purifiers. In other cases a single pipe forms both the inlet and outlet of the holder, so that only a part of the gas from each run finds its way there. In either case the speed of the exhauster is regulated so as to pass the gas made during each run within the time occupied by the run and the blow.

On leaving the purifier the gas is measured in a station meter and then passes to the storage gasholders.

The principal departure in the Merrifield-Westcott-Pearson apparatus from that of Lowe consists in the construction of the carburetter, or combined carburetter and superheater. It will be seen from Fig. 208 (p. 238) that, by the provision of the flue (6) the water gas *ascends* both carburetter and superheater. The following advantages are claimed for this arrangement—

1. Saving in ground space by having one vessel in place of two.
2. Saving in fuel by more complete utilisation of the heat.
3. That dust carried over from the generator does not settle upon the chequer brickwork; but is collected at the bottom of the flue (6), and can be easily removed.
4. Economy in oil, the lighter portions being carried upwards at once by the *ascending* gas, whilst the heavier portions, instead of being carried down and partly left at the bottom of the carburetter, have only to fall sufficiently far to become vapourised, when they are also carried upwards in the same way.

Constituting as it does the most serious item in the cost of carburetted water gas, economy in oil is of primary importance.

For the economical production of water gas it is essential: (1) that the steam be evenly distributed at the bottom of the generator; (2) that there should be a sufficient depth of incandescent fuel; and (3) that the run be not unduly prolonged. Inattention to these points results in waste of fuel and an excessive production of carbonic acid.

An analysis of water gas made under favourable conditions gives the following proportions of constituent gases:

CO_2	3.45
CO	45.56
H	50.96
N	0.03

When the apparatus is first started care must be taken lest the heat be too great in the superheater, in which case the oil is decomposed into gases of poor illuminating quality and carbon is largely deposited on the brickwork.

Afterwards, the right heat is attained, but towards the end of the run it may not be sufficient for the proper decomposition of the oil. In this respect the system may be said to compare somewhat unfavourably with others in which the oil is made into gas in retorts maintained at a uniform temperature, used either independently or in combination with water gas. Nevertheless, with ordinary care excellent results may be secured by it, Mr. Stelfox, for example, obtaining from about 1300 to 1456 candles per gallon of oil.

The composition of the finished gas varies somewhat with the illuminating power, as shown by the following analyses made by Dr. Crum Brown, sample A being of 23.5 candle and sample B of 21 candle gas.

Digitized by Google

	Sample A.	Sample B.
Carbonic anhydride	0.0	0.2
Heavy hydrocarbons	12.3	11.7
Oxygen	0.3	0.1
Carbonic oxide	32.0	32.1
Methane	21.2	21.2
Hydrogen	28.2	28.8
Nitrogen	6.3	5.9

Considerable objection has been made to the use of this gas owing to the somewhat high percentage of carbonic oxide which it contains as compared with ordinary coal gas, and also on the ground of its inferior calorific value. In Massachusetts its opponents succeeded for some years in preventing its introduction by means of a law prohibiting the distribution of any illuminating gas containing more than 10 per cent. of carbonic oxide, but this was eventually repealed, and carburetted water gas is now more largely used in that State than coal gas. In England, the Liverpool Gas Company have, in deference to public opinion, ceased to supply carburetted water gas without admixture with coal gas, the usual practice in this country being to employ it in proportion varying from 10 to 35 or 40 per cent. In a report to the Gas Committee of the Corporation of Birkenhead, Professor V. B. Lewes states that in his opinion a mixture of one-half coal and cannel gas and one-half carburetted water gas is perfectly safe as a town supply. This opinion is based upon the experiments of Dr. John Haldane, who found that 0.05 per cent. of carbonic oxide in air begins to have an appreciable effect, but can be inhaled for four hours without very marked symptoms, so that for all practical purposes, 0.05 per cent. may be taken as the margin of safety. If, then, gas escapes into a room having a capacity of 1000 cubic feet at the rate of 6 cubic feet per hour, which would represent the leakage from a burner accidentally turned on without being alight, while the air of the room is, by ventilation, changed twice in the hour, then after three to four hours the percentage of gas will rise to 0.3 per cent., and the rate of leakage and of removal by the changing of the air will become constant, and the percentage of gas will not rise above that point, however long the leakage may continue.

Taking the average of carbonic oxide present in carburetted water gas as 29 per cent. and that in coal gas as 6 per cent., then the amount of carbonic oxide—0.05 per cent.—which may be inhaled for four hours without dangerous symptoms, would be present if the escaping gas contained one-sixth, or 16.6 per cent. of such gas; and, approximately, this composition is arrived at with a mixture of one-half coal and cannel gas and one-half carburetted water gas.

In the same report, Professor Lewes deals with the question of the calorific value of carburetted water gas as compared with that of coal and cannel gas. He says:

"Our knowledge of the specific hydrocarbons of the saturated and unsaturated series present in illuminating gases is so limited, and the exact determination of the quantities present so fraught with difficulty, that no calculation of the calorific value from the analysis is possible, and determination by calorimetric methods becomes necessary. In the following determinations the Junker's calorimeter (p. 251) was used with all necessary precautions, the results being expressed in the number of pounds of water raised 1° Fahr. by the combustion of 1 cubic foot of the gas. Each result is the mean of a considerable number of closely agreeing experiments.

Digitized by Google

In the first or 'gross' determination, the heating value represents the total heat generated by the flame, and recovered from the products of combustion; but in the use of gas-stoves and in most other cases in which gaseous fuel is employed, the heat latent in the water vapour produced by the combustion escapes and is lost, and no condensation takes place. This is allowed for in the net value, which represents the heating value of the gas as ordinarily consumed:

Coal and Cannel Gas.

Gross calorific value	746.04 B.T.U.
Net „ „	675.44 „

Carburetted Water Gas.

Gross calorific value	677.08 B.T.U.
Net „ „	641.08 „

"From this it will be seen that, though there is a difference in the gross value in favour of the coal and cannel gas amounting to a little under 10 per cent. (9.4), yet in the net value, which is the one affecting the ordinary consumption in stoves, gas-cookers, &c., it is only 5.5 per cent. This is due to the carburetted water gas containing a smaller total proportion of hydrogen than is the case with the coal and cannel gas, and so forming less water vapour during combustion."

The report proceeds to give the specific gravities, determined by a Lux gas balance, of the gases under comparison, as follows:

Coal and cannel gas	0.549
Carburetted water gas	0.647

From a gasmaker's point of view, the advantages of the system of carburetted water gas are very considerable and likely to make it almost indispensable under present conditions. The rapidity with which it can be brought into use as compared with the length of time required to bring gas retorts up to the working temperature, is a very important consideration, having regard to the sudden and great fluctuations in the consumption to which all large gas undertakings are subject, and which render it a matter of difficulty with the ordinary system to ensure at all times an adequate supply. The saving in labour required for working the plant, and also in the first cost of the latter, and the ground space it occupies, are important advantages; in addition to which the manufacture of this gas opens up a greatly needed outlet for the coke produced in the manufacture of coal gas. Upon these points the following is extracted from a paper read by Mr. J. Stelfox.*

"I begin with the convenience in obtaining a supply of raw material. We have provided two tanks, each 55 feet diameter and 36 feet high (which are about half a mile from the works), and one on the works of 30 feet diameter and 20 feet high, costing, with concrete foundations, £3665. These tanks together hold about 1,160,000 gallons of oil, which will represent 386 millions of carburetted water gas of 20 candle illuminating power, equal to the production from (say) 45,000 tons of gas coal. This would represent ninety steamer cargoes of 500 tons each, to arrange for which would involve an immense amount of trouble even as regards mere freightage, as well as a constant worry in getting the coal from the ships to the stores and thence to the retort houses. In the first cargo of oil, which weighed 1930 tons (the equivalent in gas yield of nearly 20,000 tons of coal), the cargo was discharged in thirty-six working hours by the steamer's pump, through two miles of 6-inch main, and no one but the harbour and gasworks officials knew that the vessel had come and gone.

* Trans. Incorpd. Gas Inst., 1894, p. 86.

Digitized by Google

"There is great economy of space required for producing plant, &c. Enlarging on figures already given, we find that 45,000 tons of coal would cover nearly three acres to a height of 15 feet. The equivalent in oil is easily accommodated in two vessels occupying barely one-fifth of an acre, including ample room all round the tanks. The space required for producing the water gas may be put down as one-fifth that needed for retort-houses.

"These figures deal only with the ground required for gas making. It must be remembered that there is no production of coke in the manufacture of water gas, and not only is the large extent of ground required for dealing with this important residual dispensed with, but a home market is provided for a portion of the coke produced in the coal gas apparatus, thus reducing the quantity for sale in the open market, and avoiding the necessity for lowering prices so as to get rid of stock. Further, money spent in water gas plant, capable of being brought into use promptly in case of sudden emergency, would afford more relief than twice the expenditure on gas-holders, and a further economy of ground space is thus rendered possible.

"There is with water gas appliances but a comparatively small outlay on capital account. Complete manufacturing plant for the production of 2,000,000 cubic feet per day of carburetted water gas, including machinery, boilers, buildings, plant and chimney, tar settling vessels, scrubbers, &c., all complete, can be provided for £12,500. A new stage-floor retort-house for producing that quantity of coal gas, and including drawing and charging machinery, has been lately completed at the Belfast Works at the cost of upwards of £28,000, to which must be added, for comparison, the cost of boilers and scrubbers. To keep on the safe side, the saving in outlay on plant for producing that quantity of gas may be taken as £15,000, the interest on which sum, at 4 per cent., amounts to £600 per annum. Assuming that the apparatus would be at full work an average of 180 days in the year, the gas made by a plant of this capacity would be 360,000,000 cubic feet per annum, in which the £600 per annum would be 0.4*d.* per 1000 cubic feet in favour of water gas.

"The further economy in coal storage must not be overlooked. Probably three months' supply at maximum consumption would not be too much for safety (though doubtless many managers have to put up with less), and with a plant of the extent mentioned above, this would represent for oil an outlay of £1800, and for coal, if substantial sheds are to be provided, at least £18,000. The interest on the difference calculated at 4 per cent. would come to 0.43*d.* per 1000 cubic feet. If to these economies be added the value of the difference in ground space required, it may be safely assumed that there is a saving in interest on capital of quite 1*d.* per 1000 cubic feet in favour of water-gas.

"When there is anything like a good demand for coke, an enhanced price is obtained for that residual by the use of water gas. In Belfast, since early in the spring, all the surplus coke has been sold at about 18*s.* 6*d.* per ton, the price paid for coal being on the average about 15*s.* per ton. This result was mainly due to the fact that, while producing about 60 tons less coke per day than in former years, about 18 tons per day were at the same time being used in the water gas plant. We had thus about 78 tons per day, or upwards of 500 tons per week, less to dispose of. The extra receipts thus obtained for coke will, in due course, go to the credit of the coal account. It is, however, certain that the increased price (2*s.* 6*d.* per ton) would not have been obtained but for the use of the new process. As each ton of coal yields, for sale, more than 10 cwts. of coke, the extra price obtained represents at least 1*s* 3*d.* for the coke made from each ton of coal, or 1.5*d.* per 1000 cubic feet of coal gas made."

Digitized by Google

In Mr. Stelfox's view, "It would be within the power of a manager having the two systems at command to exercise a wise discretion as to their relative use. Should the coke market be brisk, the production of water gas can be reduced; but should stock, on the other hand, tend to accumulate, the production of coal gas can be checked, and correspondingly larger demands made upon the water gas plant.

"In this way, the necessity to dispose of large stocks, either by a general reduction of prices in the district (which often means the disposal of more fuel for less money), or by the sacrifice of the surplus quantity unsaleable in the district for export to other places, is avoided. It would have been quite possible for me to have supplied the city with gas from April 1 till the end of September without making a single bushel of coke for sale. In past years, when surplus stocks left each season had accumulated to a troublesome extent, this control would have been of immense value."

"The saving of labour," Mr. Stelfox states, "is immense. Working only eight-hour shifts, and giving each man only one set, each operator will make from 250,000 to 300,000 cubic feet, so that to produce 6,000,000 cubic feet per diem, the services of twenty to twenty-four operators would be required. To make this quantity of coal gas we last season employed 340 stokers."

The conclusions arrived at by Mr. Stelfox, as the result of his experience of the system, are:

"(1) That carburetted water gas of 21 candle power can be produced for less money than 17 candle coal and cannel gas, *and this without taking into consideration the saving in interest on capital and the increased revenue from coke*, not to speak of the many advantages and conveniences to which I have not ventured to attach a money value.

"(2) That the enrichment of water gas within the range of from 17 to 26 candles, or even higher, can be effected at a cost of *not more than* 0.33*d.* per candle."

This favourable view of the advantages of carburetted water gas has been rendered possible only by the comparatively low price at which oil can now be obtained.

The following table (p. 245) shows the results obtained at some of the principal gas works in which carburetted water gas is manufactured.

Acetylene.—In 1887 Mendeléeff, the famous Russian chemist, formulated a new theory to account for the production of petroleum. He was of opinion that it had a mineral origin, and was due to the action of percolating water upon glowing metallic carbides situated far beneath the crust of the earth. The water would be decomposed into its constituents, hydrogen and oxygen, the latter uniting with the metal to form an oxide, whilst the hydrogen united with the carbon to form hydrocarbons.

Petroleum had long been thought by many to be the result of the decomposition of organic remains, and the new theory, despite the respect attached to the name of Mendeléeff, commended itself to few.

During the last two or three years the classic researches of M. Moissan on chemical combination at high temperatures have done much to support Mendeléeff's theory.

M. Moissan has shown that at temperatures obtained in his experimental electric furnace the most refractory elements are vaporised, the most stable compounds are either dissociated or volatilised, and that nothing remains capable of resisting such a temperature but a series of comparatively little known compounds—the metallic borides, silicides, and especially carbides.

The electric furnace, therefore, possibly reproduces the conditions of that remote geological epoch when the carbon of all our present organic compounds was probably existent in the state of metallic carbides.

Digitized by Google

Installation.	Oil used.	Average illuminating power of gas made. Candles.	Candles. per gallon.	Cost per 1000 cubic feet.	Cost per candle per 1000 cubic feet.	Remarks.	References.
				d.	*d.*		
Beckton . . .	Solar	25.0	1292	16.53	0.66	Coke at 10*s.* 6*d.* per ton; oil at 2.62*d.* per gallon; other items included in cost taken at 3.68*d.* per 1000 cubic feet	Trans. Incorpd. Inst. Gas Engs. 1894, iv. 187
Kensal Green .	Solar	22.89	1312	17.11	0.75	Coke at 12*s.* 6*d.* per ton; oil at 2.94*d.* per gallon; other items included in cost taken at 3.38*d.* per 1000 cubic feet	Do.
Belfast . . .	Refined kerosene	21.47	1456	12.41	0.58	Coke at 15*s.* per ton; oil at 2¼*d.* per gallon; other items included in cost taken at 1.84*d.* per 1000 cubic feet	Jour. Gas Lighting 1894, lxiii. 1225
„ . . .	Solar distillate	22.73	1340	12.59	0.55	Average of 3 experiments, illuminating power 20 to 26 candles; coke at 15*s.* per ton; oil at 2¼*d.* per gallon; other items included in cost taken at 1.80*d.* per 1000 cubic feet	Do.
Glasgow . .	Broxburn blue	34.70	1218	16.52	0.48	Coke at 5*s.* per ton; oil at 2¼*d.* per gallon; other items included in cost taken at 2.37*d.* per 1000 cubic feet; average of 4 experiments, illuminating power of gas made varying from 28 to 40 candles	Jour. Gas Lighting 1895, lxvi. 230
Blackburn . .	Solar distillate	23.15	1416	14.86	0.64	Coke at 6*s.* 8*d.* per ton; oil at 3¼*d.* per gallon; other items included in cost taken at 1.71*d.* per 1000 cubic feet	Do. 1140
Tottenham . .	Refined kerosene sp. gr. 0.825	22.38	1340	15.21	0.68	Coke at 15*s.* per ton; oil at 2¼*d.* per gallon; other items included in cost taken at 4.12*d.* per 1000 cubic feet	Trans. Incorpd. Inst. Gas Engs. 1895, v. 170

Digitized by Google

These metallic carbides possess a remarkable property, namely, when simply treated with water they decompose to form hydrocarbons. Thus, from aluminium carbide, methane * is obtained, and from calcium, barium, and strontium carbides, acetylene,—

$$Al_4C_3 + 12\ H_2O = 4\ Al(OH)_3 + 3\ CH_4$$
$$CaC_2 + 2\ H_2O = Ca(OH)_2 + C_2H_2$$

whilst with their aid Mendeléeff succeeded in producing artificial petroleum.

Calcium carbide has lately acquired commercial importance owing to the discovery by Mr. T. L. Willson that it could be produced in large quantities from lime and coal dust by means of an electric furnace such as is used for the production of aluminium.

The carbide is at present being made by the Willson Aluminium Company from a mixture of lime and coke. Both are finely ground, the coke to pass through a 50-mesh sieve and the lime through a 10-mesh. Unslaked lime free from magnesia is preferred, and the coke used should contain but little ash.

The furnace is built of bricks in the shape of a bee-hive coke oven. An iron plate covered with a layer of carbon—broken "pencils," or a mixture of coke and gas tar—forms the bottom of the furnace, and at the same time serves as one of the electrodes.

The top electrode is formed of six carbon rods 4 inches square by 36 inches long, bound together at the top in an iron holder. This is connected to one of the poles of a dynamo, by a rope made of 16 $\frac{3}{4}$-inch copper cables, the iron plate at bottom of the furnace being connected to the other. The doors of the furnace having been closed, and the top electrode lowered by means of a screw worked from the dynamo-room, the current is started and the mixed coke and lime fed into the furnace at such a rate as to keep the arc covered to the height of about 1 foot around the poles. The top electrode is raised as required until a "loaf" of carbide has been formed about 2 feet high.

Large manufactories of the carbide have also been established in Austria, France, Germany, and Switzerland.

It was suggested that from the calcium carbide so made acetylene could be produced for use as an illuminant, or as an enricher of coal or water gas, and as acetylene possesses a greater illuminating value than any other known gas, and the carbide was said to be cheaply produced, the suggestion appeared very feasible.

Acetylene (C_2H_2) was first obtained by Davy in 1837 from the black mass which he obtained when making potassium. Berthelot in 1858–9 produced acetylene by passing hydrogen between the poles of an electric arc, and established the more important properties of the gas and its compounds. Wöhler in 1862 produced calcium carbide by raising a mixture of lime, zinc and carbon to a white heat. He obtained acetylene by bringing the carbide into contact with water.

Until lately, the gas has only been made in small quantities in chemical laboratories by the incomplete combustion of coal gas. The gases produced when a Bunsen burner was allowed to "light back" were aspirated through a solution of a copper salt; acetylide of copper was precipitated, which was collected and decomposed by the action of a dilute acid, acetylene being liberated.

Acetylene is a colourless gas of disagreeable odour, which is to a great extent due to impurities, and can be easily liquefied. It is an endothermic compound, decomposition being attended by the liberation of a great amount of heat. Its remarkable illuminating power, estimated at 240 candles, is no doubt due to a large extent to its endothermicity, and

* The natural gas of America consists largely of methane (see Analysis, p. 256).

Digitized by Google

Professor Lewes has shown that on passing the gas through a heated glass tube, a heat sufficient to decompose the gas with the emission of a bright light is insufficient to maintain the incandescence of the liberated carbon particles.

As an enricher of coal or water gas the present price of calcium carbide is prohibitive. Moreover, whilst pure calcium carbide yields 5.9 cubic feet of acetylene per lb., the commercial article seldom gives more than 5 cubic feet, and in some instances has been found to contain more than 50 per cent. of impurities and to yield only from 2 to 2½ cubic feet. In addition, when acetylene is diluted with other gases it fails to give a proportionate illuminating value.

The following tables show the enriching value of acetylene with various proportions of coal and water gas:—

Enrichment Value of Acetylene with Coal Gas (V. B. Lewes).*

Percentage Composition of Mixture.		Illuminating value.		Enrichment value of 1 per cent. in candles.
Coal gas.	Acetylene.	Coal gas.	Mixture.	
99.10	0.90	13	13.9	1.00
97.90	2.10	13	15.1	1.00
96.00	4.00	13	17.3	1.07
95.20	4.80	13	18.4	1.12
91.00	9.00	13	23.5	1.16
89.50	10.50	13	25.3	1.17
85.00	15.00	13	33.0	1.33
83.25	16.75	13	36.1	1.36
66.90	33.10	13	60.5	1.43
55.50	44.50	13	76.7	1.43
16.70	83.30	13	175.2	1.94
00.00	100.00	—	240.0	2.40

Enrichment Value of Acetylene with Uncarburetted Water Gas (E. G. Love).†

Acetylene. Per cent.	Water gas. Per cent.	Candle power for 5 cubic feet of the mixture.	Illuminating value of acetylene. Candles.
14.36	85.64	1.14	7.94
18.38	81.62	11.65	63.38
24.66	75.34	29.45	119.42
27.84	72.16	40.87	146.80
38.00	62.00	73.96	194.63

Thus when acetylene is mixed in small proportions with coal gas its illuminating value may be lowered by more than 50 per cent.; whilst when mixed with uncarburetted water gas the loss is much greater.

In isolated places, such as country houses, lighthouses, &c., and for lighting railway carriages, the use of the gas is extending, though at present it is regarded with some distrust on account of the number of accidents which have attended its introduction. Great care is evidently required in

* Trans. Inst. of Gas Engs., 1895, vol. v. 127.
† Jour. Gas Lighting, 1895, lxvi. 335.

Digitized by Google

its use, as on account of its endothermic property its decomposition is easily effected when under pressure, and takes place with explosive violence. As acetylene forms an explosive compound with copper, the use of this metal is to be avoided.

Another danger arises from the use of impure calcium carbide, in that phosphoretted hydrogen may be generated along with the acetylene.

The number of apparatus which have been patented for the production of acetylene from calcium carbide is legion, and the majority of them are useless. Many of them resemble the ordinary Kipps' apparatus for producing carbonic acid in the laboratory, water taking the place of the dilute acid and calcium carbide that of the calcium carbonate. Unfortunately, however, calcium carbide continues to evolve acetylene after the removal of the water on account of the presence of aqueous vapour, and the gas so generated whilst the apparatus is not in use accumulates until sufficient pressure is generated to force the water seal. Dr. Frank Clowes has shown* that the range of explosibility of acetylene mixed with air is greater than that of any other gas; escapes, therefore, must be strictly avoided.

Calcium carbide has lately been brought under the provisions of the Petroleum Act, 1871, and the Home Office has issued instructions to local authorities that when granting licences provision should be made:

1. For the exclusive use of hermetically closed packages for the keeping and conveying of carbide of calcium.†

2. The adequate ventilation of the place where the carbide of calcium is present.

3. The prohibition of any powerful compression of gas produced in the apparatus or receptacles employed.

4. The keeping and use of pure carbide of calcium only, and the establishment of efficient arrangements for the sampling and testing of the carbide.

5. The exclusion of copper from all vessels or apparatus used with or for carbide of calcium and the gas produced therefrom.

6. The use only of an apparatus which the local authority have satisfied themselves, under competent advice, is of a safe and suitable character, and the prohibition of the employment for the manipulation of such apparatus of any person other than a properly instructed and capable operator.

7. The safe disposal of the residue, and the prohibition of its introduction into sewers, cesspools, &c., unless mixed with at least ten times its bulk of water.

It will in all cases be for the local authority very carefully to determine whether the premises proposed to be licensed are themselves suitable for the purpose, regard being had to the formidable consequences from fire or explosion which might result from the careless or imperfect observance of any of the imposed conditions, especially in dwellings or in places or premises where large numbers of persons are liable to assemble.

These regulations, though no doubt calculated to check the use of acetylene, will if properly carried out prevent the occurrence of many accidents.

Rule 3 debars the use of liquid acetylene which, despite the fact that the carriage of sufficient calcium carbide to produce an equal quantity of the gas would be the more economical, is the most suitable form in which to make use of the new illuminant.

A novel method of using compressed acetylene, however, has recently

* Jour. Soc. Chem. Industry, 1896, xv. 418.

† The ninth section of the Petroleum Act specifies, among the conditions which may be included in a licence under that Act, the mode of carrying within the district of the licensing authority.

Digitized by Google

been discovered by MM. Claude and Hess which, it is maintained, is without danger.* Acetylene is supplied in cylinders containing acetone, a liquid in which the gas is dissolved under pressure. Upon opening the tap the acetylene is given up by the liquid, and after it has all been evolved the acetone may be recharged with the gas. On account of the great solubility of acetylene in acetone under compression and the lower co-efficient of expansion of the acetone, it is stated that as much, or even more, acetylene, dissolved in acetone, can be put into a cylinder, as if no acetone were present.

CHAPTER XXI.

Combustion.

Before entering on the subject of the application of coal gas as a lighting and heating agent, and as a means of obtaining motive power, it is perhaps desirable to give a brief review of the phenomena of Combustion, and of the means adopted for measuring the heating power of combustible gases. Combustion is said to occur when two or more substances act on one another with the production of one or more dissimilar compounds, the action being accompanied by the evolution of heat. As ordinarily accepted, the term is applied to the action which takes place when substances having a great affinity for oxygen unite with the oxygen contained in the atmosphere with such development of heat that they are raised to incandescence. Such substances are termed combustibles, whilst the air, that is, the oxygen of the air, is spoken of as the supporter of combustion. As was pointed out by Kemp, however, these terms are reversible; thus, given an atmosphere of coal gas, oxygen will become a "combustible"; for, as shown in the well-known lecture experiment, a jet of it may be ignited and burnt in a vessel filled with coal gas.

In the same way that all substances when entering into combination do so in definite proportions by weight, so such combinations are always attended by the absorption or development of a definite quantity of heat. Thus, in the case of the combination of hydrogen with oxygen, 1 kilogram of hydrogen will unite with 8 kilograms of oxygen, and their union will be attended by the production of 34,600 "calories" or units of heat, one calorie representing the amount of heat required to raise 1 kilogram of water, at a temperature near the freezing point, 1° C. The unit of heat frequently used in this country, and known as the British Thermal Unit (B. T. U.), represents the amount of heat required to raise 1 lb. of water 1° F. in temperature. The calorific power of hydrogen under the English system, therefore, is $34{,}600 \times \frac{9}{5} = 62{,}280$ B. T. U.; 1 lb. of hydrogen in burning to water liberating sufficient heat to raise 62,280 lbs. of water 1° F. Such compounds as water, in the production of which heat is liberated, are known as exothermic. Compounds such as acetylene, in the production of which heat is absorbed, are known as endothermic.

In order to determine the calorific power of various combustibles, instruments known as calorimeters are used, in which a weighed or measured quantity of the substance is burnt with the requisite quantity of air or

* Jour. Gas Lighting, 1897, lxix. 886.

Digitized by Google

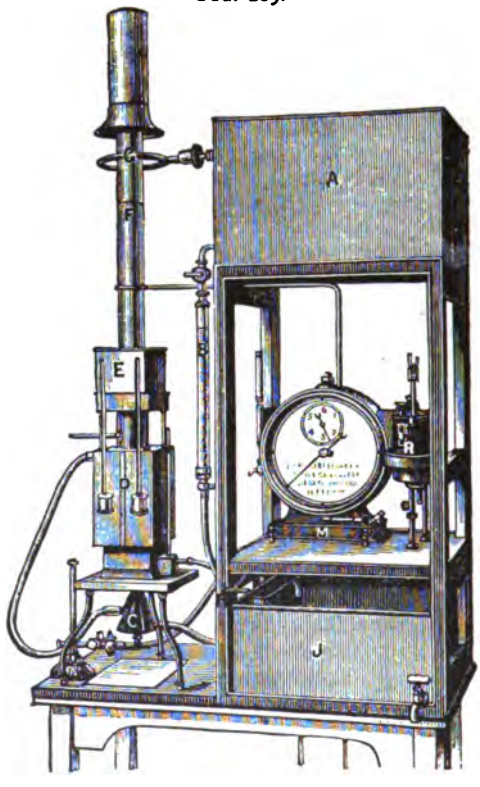
oxygen, and the heat liberated entirely communicated to a weighed quantity of water, from the rise in temperature of which the calorific value of the combustible can be ascertained.

Instruments suitable for determining the calorific value of coal and coke are described in Vol. I. of this work—"Fuel."

For ascertaining the calorific power of combustible gases, a simple gas calorimeter devised by Hartley is illustrated. (Fig. 209.)

D is a jacketed vessel similar internally to a Coffey still. It is provided with a copper chimney F, the upper part of which is heated by the circular burner G, simply to produce the necessary aspiration of the products of combustion of the gas under examination. Underneath D is the water-jacketed burner C, where the gas, after measurement by an accurate gas meter M, is burnt at the rate of about 1½ cubic feet per hour. Water is run from the cistern A through the glass tube B, containing a sensitive thermometer graduated into tenths of a degree F°, round the burner C to the inlet of the vessel D, down which it flows, abstracting the whole of the heat liberated by the gas consumed. At the bottom of D the water flows through a projecting lip, containing a thermometer for indicating its temperature, into a collecting cistern J, from which at the end of an experiment it can be measured.

FIG. 209.



Hartley's Calorimeter.

To use the apparatus, the gas consumption and flow of water are so regulated that the temperature of the latter is raised from about 4° F. below to 4° F. above the atmospheric temperature, whilst the thermometer in the chimney indicates no rise in temperature. When the mercury in the thermometer for indicating the temperature of the outlet water remains steady, the meter hand is set nearly at zero, and the moment it reaches it, the water issuing from the apparatus, which had previously been run to waste, is diverted into the collecting cistern J, to be as suddenly re-diverted when ¼ cubic foot of gas has been consumed. Whilst this is taking place, observations are made of the temperature of the water at the inlet and outlet, and also of the jacketed body of the calorimeter. This has been found to absorb an amount of heat equal to 0.025 of a degree per minute for every degree which it is below, and the receiver at the bottom to lose 0.01 of a degree per minute for every degree which it is above the temperature of its surroundings.

Example:

Digitized by Google

Gas burnt in calorimeter, ½ cubic foot, 32° F., 30 in. Bar.
Atmospheric temperature, 60° F.
Temperature of water-inlet of calorimeter, 56° F.
„ „ outlet „ 64° F.
Quantity of water passed through calorimeter during burning of ½ cubic foot, 20 lbs.

Then 20 × 4 = 80 lbs. if 1 cubic foot were burnt, which multiplied by 8, the rise in temperature of the water, = 640 B. T. U. per 1 cubic foot of gas. This, however, is subject to a correction for radiation from the body of the calorimeter and receiver, the former having a temperature of 56° F. and the latter 64° F. during the ten minutes the experiment lasted.

0.025 × 4 × 10 = 1.0° F.
0.010 × 4 × 10 = 0.4° „

0.6° „

Or for 1 cubic foot 0.6 × 4 = 2.4° F.
A calorific value of 1 cubic foot of the gas was 640 − 2.4 = 637.6 B. T. U.

Junker's Calorimeter.—A flame, 28, Fig. 210, is introduced into a combustion chamber, formed by an annular copper vessel, the annular space being traversed by a great number of copper tubes, 30, Figs. 210 and 211, connecting the roof with the bottom chamber. The heated gases circulate inside the tubes from the top to the bottom, whilst a current of water ascends outside the tubes in the opposite direction. By means of this most suitable arrangement of counter currents, all the heat produced by the flame is transferred to the water, and the spent gases escape through the throttle valve at the atmospheric temperature.

The pressure of the water current is kept constant by two overflows, 3 and 20, and the quantity of water passing the apparatus can be regulated by the stopcock 9. A baffle plate, 14, surrounds the lower end of the tubes to ensure an even distribution of the water, and in the neck of the apparatus, at 38, several discs with cross slots are arranged to ensure an intimate mixture of the heated water before it reaches the thermometer.

Provision is made to collect the water which is formed during the combustion of many gases in the annular space 34, and to pass it into a measure glass through the tube 35.

To prevent radiation, the whole body of the apparatus is enclosed in an air-jacket formed by a highly-polished nickel-plated copper cylinder.

The calorimeter is placed as shown in Fig. 211, so that one operator can simultaneously observe the two thermometers of the entering and escaping water, the index of the gas-meter and the measuring glasses.

No draught of air must be permitted to strike the exhaust of the spent gas.

The water supply tube is connected to the nipple *a*, in the centre of the upper container, the other nipple is provided with a waste tube to carry away the overflow. This overflow must be kept running while the readings are being taken, and in order to observe this, a short piece of glass tube may be inserted in the waste tube.

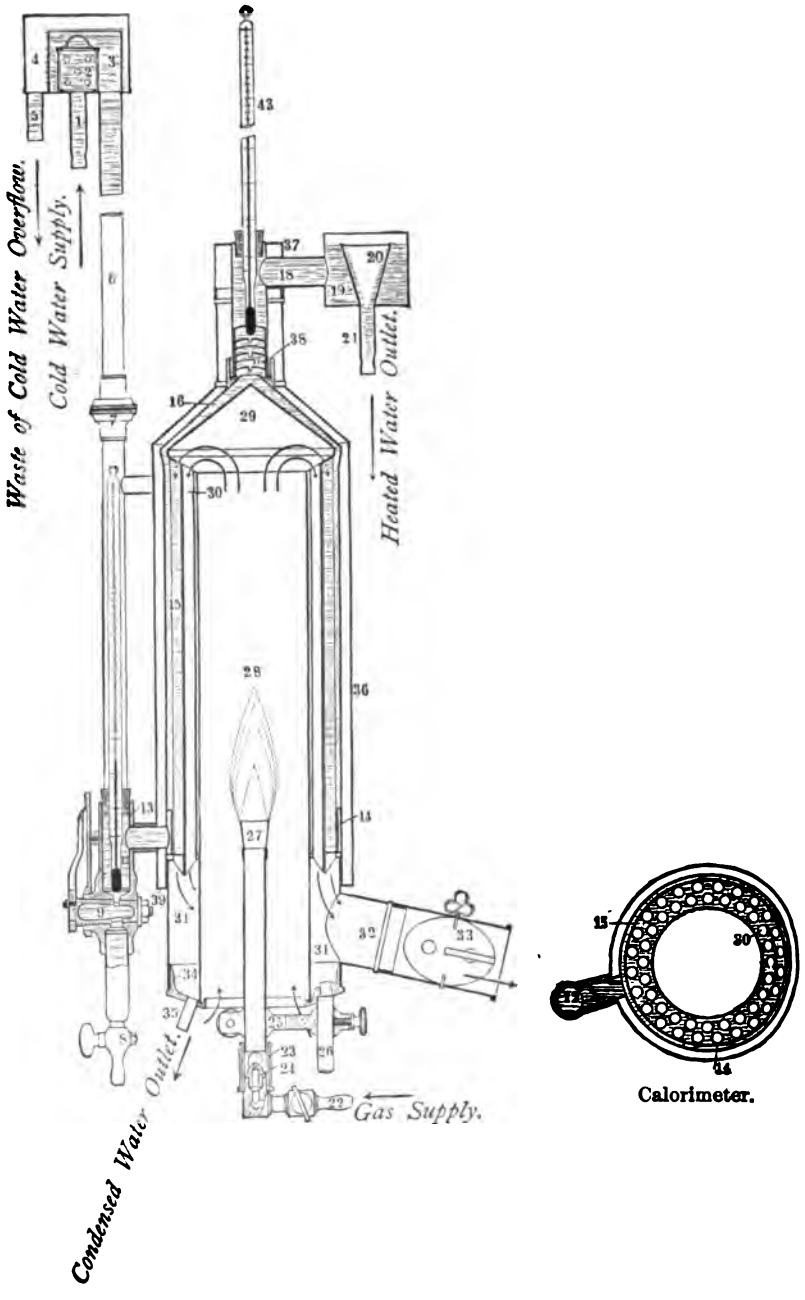
The nipple *c*, through which the heated water leaves the calorimeter, is connected by an indiarubber pipe with the large measure glass, and the water must be there collected without splashing.

The smaller measure glass is placed under the tube *d*, to collect any condensed water.

After the thermometers have been placed in position with their indiarubber plugs, the water supply is turned on by the cock *e*, and the calorimeter filled with water until it begins to discharge at *c*. No water must at

Digitized by Google

FIG. 210.



Vertical Section.

Calorimeter.

Horizontal Section

Junker's Calorimeter.

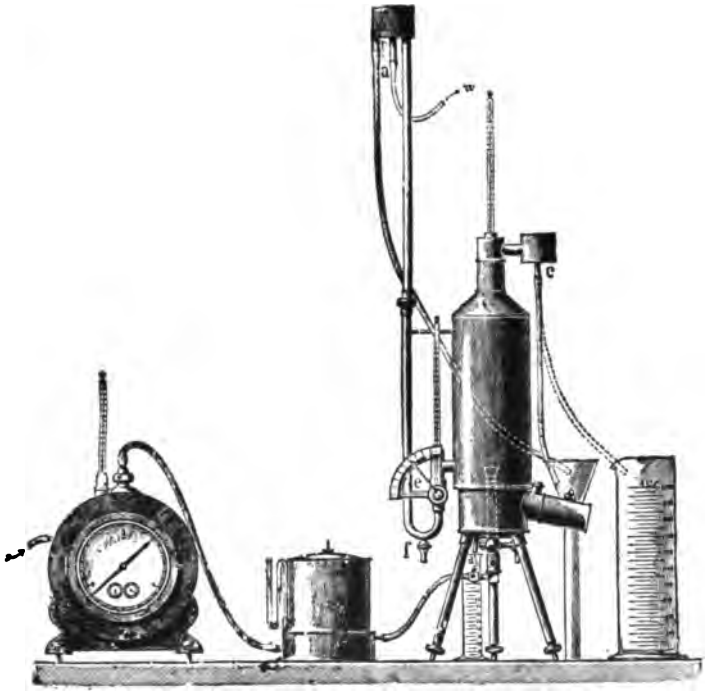
Digitized by Google

this period fall from the small pipe at *d*, or from the test hole under the air jacket, otherwise this would prove the calorimeter to be leaking.

For gases of high calorific power (illuminating gas, for example), the burner furnished with the calorimeter should be used; for gases of lower power (such as hydrogen, carbonic oxide, Dowson's water gas, &c.), the plain metal tube serves as a burner.

The calorimeter has a maximum capacity of absorbing 2500 calories per hour; the quantity of gas burned during the tests should therefore be regulated, so that the flame produces only about 1000 to 1500 calories per

FIG. 211.



Junker's Calorimeter.

hour. This will be the case with average qualities if the respective gases are burned at the rate of the following quantities per hour:

Illuminating gas	4 to 8 cubic ft.
Hydrogen	8 „ 16 „
Dowson's gas	16 „ 32 „

Before beginning the experiments, try whether the gas conduit from the meter to the apparatus is perfectly tight by opening the supply main, closing the tap on the burner, and observing that the indicating pointer of the meter remains stationary; then turn on the water, and fill the calorimeter until water appears at the water-discharge, making sure that the overflow is working freely. The burner should always be lighted outside of the combustion chamber, to avoid explosions of accumulated gas.

Insert the burner so that the bottom of the flame is 5 to 6 inches above the lower edge of the apparatus.

Digitized by Google

The throttle-valve at the exhaust of the spent gas can be used to regulate the access of air to the flame; its use is, however, rarely required.

When the flame is burning, and the water flowing, the temperature of the water at the discharge will begin to rise, and, within a few minutes, the exit thermometer will remain approximately stationary.

The cock *e* regulates the quantity of water passing through the calorimeter, and the heat produced by the flame being a constant quantity, the less the quantity of water passing, the higher its temperature will become. Ten to twenty degrees Centigrade is the most suitable rise in temperature to work with, and on no account should the increase exceed the range of the thermometer, as otherwise it would burst.

When the pointer of the gas-meter passes zero, or a whole figure, shift the hot-water tube from over the funnel into the measuring glass, and read and note down the temperature of the hot water thermometer at five or six intervals while the glass is being filled, which will take from one to five minutes. The cold-water thermometer will generally remain stationary, and need only be observed once. As soon as the hot water reaches the two-litre mark, turn the gas off, and read the quantity of gas shown by the meter.

The following figures will serve as an example:

Gas Meter.	Cold Water Thermometer.	Hot Water Thermometer.
5.0 cubic ft.	15.45° C.	22.65° C.
	"	22.64°
	"	22.60°
	"	22.61°
	"	22.61°
	"	22.63°
	"	22.65°
	"	22.64°
	"	22.62°
5.23 cubic ft.	15.45° C.	22.59°
Gas burnt 0.23 cubic ft.	15.45° C. average	22.624° C. average

The water collected in the measuring flask was 5000 c.c.

A calorie being the quantity of heat required to raise the temperature of 1 litre (1000 grams) of water 1 degree C., the experiment will show the heating value of the gas by means of the following equation:

$$H = \frac{W\ T}{G}$$

where H is the calorific value of 1 cubic foot of gas.
W is the quantity in litres of water heated.
T is the difference of the temperature, in degrees C., of the inflowing and of the outflowing water.
G is the quantity of gas in cubic feet burned during the experiment.

The above example would therefore give the result:

$W = 5 \quad T = 22.624 - 15.45 = 7.174° \quad G = .23$

and $H = \frac{5 \times 7.174}{.23} = 155.9$ calories per 1 cubic foot.

Which, multiplied by 3.968, = 618.6 B. T. U.

Digitized by Google

It is evident that the reading may be modified by burning a certain quantity of gas, say ½ cubic foot, and measuring the amount of water heated by its combustion.

It should be observed that this is a "gross" value, which represents the total heat generated by the flame, including the whole of that of the hydrogen contained in the gas, which in the calorimeter is condensed from steam to water, and gives up its latent heat of vaporisation to the circulating water. This latent heat is, however, utilised in scarcely any industrial process where gaseous fuel is used. From gas fires and gas engines, for example, all the water which is formed escapes as steam.

It is therefore of importance to ascertain the "nett" calorific value of the gas used in such processes, which in many cases is 10 per cent. less than the gross value.

The calorimeter gives a ready method of determining the difference between these gross and nett values, as we have only to measure the quantity of water condensed in the apparatus and collected in the small measuring glass. For every cubic centimetre of this water, an allowance of 0.6 calorie must be made. As the quantity of water produced is proportionately small, it is advisable to burn a large quantity of gas, say 2 to 3 cubic feet, for these determinations.

As the calorific power of each constituent of coal gas has been ascertained with considerable accuracy, it is possible to obtain a close approximation to the calorific value of any sample of coal gas, provided an analysis of the same has been made. In the following table is given the calorific power of the principal constituents of coal gas, expressed in calories per cubic metre, and in B. T. U.s per cubic foot, on the assumption that none of the steam produced by the burning of the hydrogen is condensed to water:

	Calorific power of 1 cubic metre. Calories.	Calorific power of 1 cubic foot. B. T. U.
Hydrogen	2,600	292.1
Methane	8,555	961.2
Ethane	15,905	1787.1
Propane	22,800	2561.8
Butane	30,070	3378.7
Pentane	37,325	4193.9
Ethylene	14,285	1605.1
Propylene	21,200	2382.1
Butylene	29,010	3259.6
Benzene (gaseous)	33 705	3787.2
Toluene „	39,735	4464.7
Carbon monoxide	3,034	341.0

Below are given the calorific values, calculated from the analyses by means of the above data, of representative samples of coal gas, natural gas, and water gas.

Digitized by Google

Constituents.	Water gas from a large iron works near Birmingham.			Carburetted water gas, 20 candles.			Birmingham coal gas. 17 candles.			Natural gas. Average of 16 analyses of the gas from various parts of the U.S.A.		
	Per-centage.	B. T. U. per cubic ft.	B. T. U.	Per-centage.	B. T. U. per cubic ft.	B. T. U.	Per-centage.	B. T. U. per cubic ft.	B. T. U.	Per-centage.	B. T. U. per cubic ft.	B. T. U.
Methane	1.8	× 961	= 1,730	14.3	× 961	= 13,742	35.8	× 961	= 34,404	73.5	× 961	= 70,633
Ethane	—	—	—	—	—	—	—	—	—	4.3	× 1,787	= 7,684
Benzene	—	—	—	2.0*	× 3,787	= 7,574	1.0*	× 3,787	= 3,787	—	—	—
Ethylene	—	—	—	9.2	× 1,605	= 14,766	3.8	× 1,605	= 6,099	0.7	× 1,605	= 1,123
Hydrogen	44.4	× 292	= 12,965	35.5	× 292	= 10,366	48.9	× 292	= 14,279	12.3	× 292	= 3,592
Carbon monoxide . . .	39.3	× 341	= 13,401	31.5	× 341	= 10,741	6.6	× 341	= 2,251	0.6	× 341	= 205
Carbon dioxide	5.6	—	—	0.0	—	—	0.0	—	—	1.3	—	—
Oxygen	0.5	—	—	0.0	—	—	0.0	—	—	1.2	—	—
Nitrogen	8.4	—	—	7.5	—	—	3.9	—	—	6.1	—	—
	100.0		28,096	100.0		57,189	100.0		60,820	100.0		83,237
B. T. U. per cubic foot . .			281			572			608			832

* Estimated.

N.B —These figures do not include the latent heat of steam produced by the burning of hydrogen, free or combined. The calorific value of heating gases generally includes this ; but as such heat is lost in actual working, it seems advisable to exclude it.

Digitized by Google

CHAPTER XXII.

Gas-Burners.

THIS is a subject of scarcely less importance than economical carbonising, seeing how easily the efforts of the engineer may be frustrated by the depreciating effect of inefficient burners. In a Report to the Board of Trade in 1871, the Gas Referees thus expressed their opinion with regard to it:—"Every improvement in the construction of gas-burners is equivalent, in its economical effects, to the discovery of a method of cheapening the manufacture and supply of gas; for it enables the public to obtain more light from the gas which they consume and pay for. By using good burners instead of bad ones, consumers may obtain from 30 to 50 per cent. more light, while their gas bill remains the same." They further stated that in the course of their investigations relative to the choice of a standard burner, they made and tested a large collection of burners of all kinds, obtained from the leading gas-fitting establishments and other quarters; and, in consequence of the great numerical preponderance of bad burners in the collection, they were led to inspect the gas-lighting arrangements in several large establishments in the City, especially those in which, owing to the prevalence of night-work, an unusually large quantity of gas is consumed. The inspection fully confirmed the apprehension, which the Referees had formed from their examination of the burners procured from the gas-fitting establishments. For example, in the offices of two of the daily newspapers (establishments which consume more gas than any others), it was found that the burners chiefly in use were so defective that they gave out only *one-half* of the illuminating power of the gas actually consumed; and several of the burners tested by the Referees gave only *one fourth*. These facts, and many others which came to their knowledge, proved to the Referees that "an enormous waste of gas prevails, with a corresponding pecuniary loss to the public."

Since the date of this Report great advances have been made, both in general appreciation of the subject and in the introduction of improved burners; nevertheless a very large majority of the ordinary burners in present use do not give out more than about two-thirds of the illuminating power of the gas. These, however, are being rapidly superseded by the system of incandescent lighting which has been greatly developed during the last few years.

Not only was the construction of gas-burners very imperfectly understood, "even," according to Mr. R. H. Patterson, "the cleverest of our manufacturers working empirically, or at most merely groping after the principles which regulate the development of gas light," but also amongst scientific men these principles were far from being realised. The idea prevailed that the illuminating power of coal-gas varies with the different quantities of gas consumed in the burner, "the light increasing, not in direct proportion, but in some greater though undetermined ratio, with the increased consumption." Messrs. Christison and Turner, of Edinburgh, were the first to promulgate this theory as far back as about the year 1825, and it was favoured by other and more recent investigations. It culminated at length in the strange doctrine, announced in 1869–70 by Mr. W. Farmer, Photometric Observer to the Manhattan Gas Co., New York, that the illuminating power of the gas rises in a geometrical ratio as the square of the quantity of gas consumed. That is to say, six cubic feet of gas

Digitized by Google

gives, not double, but four times the amount of light given by one-half the quantity, or three cubic feet. So improbable did this appear, that inquiry was at once directed to the general question, and although an endeavour was made by Dr. Pole * to establish a new ratio, viz., "that during the normal state of action of a gas-burner, the light given varies directly as the consumption, minus a constant quantity," the experiments published by the author in 1870–71, and the Report of the Gas Referees in the latter year, already referred to, in which this subject was dealt with, were accepted as conclusively proving that the development of light takes place in simple arithmetical ratio, provided the gas is consumed in a burner suitable for each particular rate of consumption Otherwise variations may occur, which, however, are entirely attributable to the influence of the burner. Different rates of consumption and different qualities of gas require different burners. There are limits to the highest efficiency of every burner of whatever kind, and the aim should be to restrict its employment within these limits.

Argand Burners.—As early as the year 1815, Clegg and Grafton enunciated the principles upon which Argand burners should be constructed so as to be capable of properly developing the illuminating power of the gas; and of these Mr. W. Sugg, himself an authority on the subject, has declared † that burners so made "must have been nearly equal to the best that can now be produced." Their teaching, however, appears to have been wholly ignored or forgotten; and the half-century or so which followed was a period of absolute retrogression as regards the Argand burner, although it produced the batswing burner, which, imperfect though it be, was yet a very decided improvement upon the "single jet" and "cockspur" burner, Fig. 212, which formed the only alternatives to the Argand in the early days of gas-lighting. Many so-called improved Argands were introduced to the public, but most of them of almost unmitigated badness, betraying complete ignorance of the proper methods of construction; nor was it until 1862 that any real improvement began to be made. In that year, the labours of the late Dr. Letheby and of Mr. W. Sugg resulted in what is known as the Sugg-Letheby burner, which was welcomed as an important advance on the ordinary "15-hole Argand with 7-inch chimney," until then specified in all Parliamentary enactments as the standard burner. This burner was, however, destined to give place a few years later to a still better one, designed by Mr. W. Sugg, since known as Sugg's No. 1 London Argand, and subsequently adopted by the Gas Referees as the standard burner for testing common gas. The successive improvements thus established are indicated by the values given to what, previous to 1862, was recognised as 12-candle gas. This by the Sugg-Letheby burner became transformed into 14-candle gas; and a further two candles, making it 16 candles, were added by Sugg's London Argand. Thus an increase of illuminating power of four candles, or 33⅓ per cent., was effected by the substitution of a burner of improved construction; and an enormous economy was proved to be within the reach of gas consumers. It is only right, however, to say that prior to the Sugg-Letheby burner there was in existence a burner known as the "Birmingham" burner, which answered to the Parliamentary definition of

FIG. 212.

The Cockspur Burner.

* Jour. of Gas Lighting, 1870, pp. 778–813.
† Proceedings of British Association of Gas Managers, 1869.

Digitized by Google

"15-holes with 7-inch chimney," and gave results only slightly inferior to the former, but it was very little used, whilst the standard burner used in Paris, called the "Bengel," gave a light superior to any English production prior to Sugg's London Argand. This burner had not, however, attracted any notice in this country.

The Argand burner is a modification of the old Argand oil-lamp. In place of a wick, the top of the burner is perforated with holes through which the gas issues in single jets, the holes being placed close enough to enable the jets to unite, and so form a solid circle of flame within the glass chimney. Two currents of air impinge upon the flame, one rising up through the centre opening of the burner and acting on its interior surface, and the other between the interior of the glass chimney and the exterior of the burner. The proper regulation of the air supply is essential for securing luminous combustion, for if a large excess of air be admitted all luminosity will disappear, while, on the other hand, the admission of too little air will result in a smoky yellow flame. It follows that the area of the air passages must be correctly proportioned to the requirements of luminous combustion, regard being had to the influence on the quantity of air admitted which is exerted by the height of the chimney and the pressure at which the gas issues from the burner. After Clegg's time, one of the principal mistakes made in the construction of Argand burners was in having the holes of very small size, which necessitated a high pressure at the point of ignition. This high pressure induced a more rapid delivery of air to the burner than was necessary to support luminous combustion, and this resulted in great loss of illuminating power. In like manner, the chimney influences the air supply, for without it the flame of an Argand burner is smoky, unsteady, and feebly luminous. The highest illuminating power per foot consumed is attained when the flame is on the point of smoking, or when the top of it is about level with the top of the chimney. If, on the other hand, the gas be turned down, the luminosity of the flame may almost disappear, in consequence of the excess of air which is induced by the heated current within the chimney. How readily coal-gas may be caused to lose all luminosity is shown by the Bunsen burner, in which air is mixed with the gas at the entrance to the burner. The non-luminous flame thus produced is, owing to the excess of air, somewhat lower in temperature than the luminous flame of a good burner. As illustrating the evil effect of an over-supply of air with Argand burners, the following experiments may be quoted. They were made by the author with the object of testing the accuracy of the "Farmer" theorem, and they show that economy in the consumption of gas can only be attained by the systematic employment of burners at their highest point of efficiency.

Sugg's London Argand, 6-inch Chimney.

Consumption per hour. Cubic feet.	Illuminating value in sperm candles.	Illuminating value in sperm candles per foot consumed.
5.964	19.39	3.25
5.208	15.91	3.05
4.992	14.94	2.99
4.576	13.36	2.92
3.528	6.12	1.73
2.472	1.37	0.55
2 004	0.47	0.23

Digitized by Google

French Bengel, 8-inch Chimney.

Consumption per hour. Cubic feet.	Illuminating value in sperm candles.	Illuminating value in sperm candles per foot consumed.
5.248	15.79	3.01
4.488	13.25	2.95
3.540	8.72	2.46
2.580	4.00	1.55
1.542	0.66	0.43

15-hole Standard Argand, 7-inch Chimney.

Consumption per hour. Cubic feet.	Illuminating value in sperm candles.	Illuminating value in sperm candles per foot consumed.
5.904	17.54	2.97
4.872	13.41	2.75
3.924	9.55	2.43
2.718	3.93	1.44
1.482	0.49	0.33

The third column shows that gas, capable, under favourable conditions, of yielding from about 3 to 3¼ candles per cubic foot consumed may be so depreciated in value by an excess of air as to yield, with the same burner, as little as $\frac{1}{15}$th of the amount; whilst the following experiment proves that this depreciation may be avoided by reducing the height of the chimney according to the consumption; in other words, regulating the supply of air to the requirements of luminous combustion.

Sugg's London Argand.

Height of Chimney.	Consumption per hour. Cubic feet.	Comparative value. Standard of comparison = 1.	Proportionate value of 5 feet by calculation.
6 inches . .	5.424	1.025	0.945
4⅝ „ . .	4.500	0.860	0.955
4¼ „ . .	4.056	0.767	0.945
3⅝ „ . .	3.756	0.720	0.958

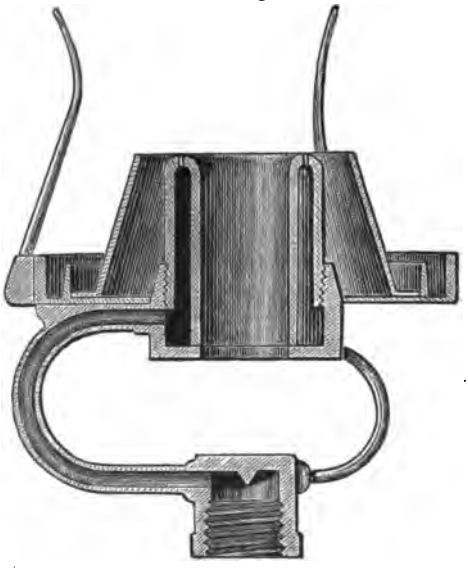
The proportionate value of the gas as shown by the fourth column is substantially the same at each rate of consumption, although by reference to the previous experiments with the same burner it will be seen that very considerable depreciation takes place within practically the same limits of consumption when the height of the chimney remains the same. It is probable that this depreciation is entirely due to the cooling effect of the air. To keep the flame hot, therefore, is or should be the aim of all burner manufacturers, because luminous development depends upon the carbon particles being highly incandescent. Thus the substitution for the tops of burners, of steatite or enamel, being non-conductors of heat, in the place of iron, which is a good conductor, was found to add appreciably to the illuminating power of the gas, by checking the escape of heat, and so increasing the temperature of the

Digitized by Google

flame. The first application of steatite to Argand burners was by Messrs. Sugg and Letheby. In its natural state it is so soft as to be readily worked to any form, but when heated to about 2000° F., it becomes extremely hard, without losing its shape.

In the year 1862, MM. Audouin and Bérard of Paris published the results of some exhaustive experiments on gas-burners, which, even at this distance of time, deserve careful study. One object of their inquiry was to determine the quantity of air required for luminous combustion, and, generally, the effect on the illuminating power of increasing or diminishing the air supply. For the details of these experiments the reader is referred to the translation published by the "Journal of Gas Lighting" (vol. xi. p. 733); but it may be stated that MM. Audouin and Bérard found that with gas of the quality used in their experiment a maximum illuminating power was found for a quantity of about 20 cubic feet of air supplied externally, and 4½ cubic feet supplied internally, to the flame of an Argand burner consuming 3¾ cubic feet of gas. By slightly increasing the quantity of air, in the same proportion, the flame became better, contracted somewhat, took a more defined form, and was less elongated without any considerable diminution in the illuminating power. The total quantity of air producing the maximum result was equal to 6½ times the volume of the gas. As to variations in the quantity of air supplied to the burner it is said that "it is possible to cause variations in the intensity of the light produced, from the same quantity of gas, in the proportions of from 1 to 2.59 by varying the quantity of air supplied in the proportion of from 1 to 1.47."

FIG. 213.



The London Argand.

The Argand burners principally in use at the present time in this country are the inventions of Mr. W. Sugg, whose name is inseparably associated with the great advances in the art of gas illumination that have taken place during the last thirty years. Reference has already been made to the London Argand, Fig. 213, which in 1869 was adopted by the Gas Referees as the standard burner for testing common gas. In the construction of this burner Mr. Sugg has very carefully worked out the proportions, both of the burner itself and of the air passages, while the discovery of the suitability of steatite for the top of the burner has contributed to the result achieved. The holes, twenty-four in number, through which the gas issues, are of ample dimensions, enabling the supply to be maintained with the lowest possible pressure; and the white metal cone surrounding the burner directs the external air supply to the lower portion of the flame.

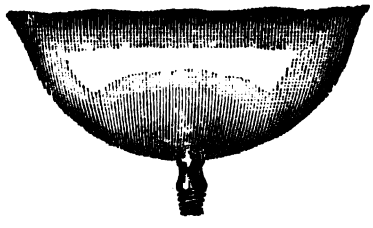
The standard burner has one defect, if that may be called a defect which is capable of being remedied by an alteration in the mode of its use. With a uniform height of chimney and with a consumption of 5 cubic feet per hour as prescribed by the Gas Referees, it exaggerates the deficiencies of

Digitized by Google

inferior gas or of gas which happens to be below the value of about 17 candles, and it does not give the correct value of gas of the same quality at different rates of consumption (see experiment, p. 259). To a very great extent these objections may be met by altering the height of the chimney according to the quality or consumption, as is apparent from the experiment quoted on p. 260; but for testing purposes it would be more satisfactory if, instead of the rate of consumption being fixed at 5 cubic feet per hour, at which the illuminating power of the gas ordinarily supplied is not usually fully developed, the rule were to allow the gas flame to fairly fill the 6-inch chimney, without tailing over, correcting the results obtained with the consumption of gas necessary to effect this to the standard rate of 5 cubic feet.

Great as was the improvement achieved by the standard Argand, Mr. Sugg has since surpassed it in the production of his series of improved London Argands, which are adapted for different rates of consumption, extending beyond 5 feet per hour, and also for various qualities of gas, including what is known as cannel gas, the illuminating power of which had hitherto been determined by flat-flame burners. Those for ordinary gas afford an illuminating power exceeding that yielded by the standard Argand by fully 10 per cent., while the cannel Argands give a result greatly superior to that which is obtained with the ordinary batswing. In addition, multiple Argands, that is, having more than one ring of jets, the rings being placed concentrically, have been introduced by Mr. Sugg for street lighting and other purposes. These are made in sizes giving an illuminating power of from 50 to 400 candles and upwards, and were certified by Messrs. Dibdin and Foster, the Examiners appointed in 1883 by the Committee of the Crystal Palace Gas and Electricity Exhibition, to yield from 4.25 to 4.77 candles per cubic foot of gas consumed per hour, as against, say, 3.25 candles yielded by the standard Argand with the same quality of gas.

FIG. 214.



Batswing Burner.

Flat-flame Burners.—Notwithstanding these great advances, it cannot be said that the Argand burner has grown in popular favour, or that its use for other than testing purposes has appreciably extended during recent years. This is partly owing to its cost, and the inconvenience resulting from the glass chimney, which is its necessary accompaniment; but chiefly perhaps because the improvement in flat-flame burners, which are the cheapest and at the same time the most convenient for ordinary requirements, have almost, if not quite, kept pace with the development of the Argand. For many years this class of burners was solely represented by the batswing, Fig. 214. The union jet, or fishtail, is stated to have been the joint invention of J. B. Neilson, of hot-blast celebrity, and James Milne, both of Glasgow. They found that two equal jets when impinging upon each other in an oblique direction produced a flat flame with increased light. Separate nipples were employed at first, but it was soon found possible to drill two holes, at the required angle, in the same nipple. This method of construction has continued, with little alteration, down to the present time. Provided the holes are of suitable size, and are placed at a proper angle, this burner is capable of giving very good results, but unfortunately manufacturers have too often appeared to proceed on the assumption that the amount of pressure by which the gas is forced through the burner is of little consequence. Hence the holes have been made too small, and as this burner is both cheaper and less liable to injury than

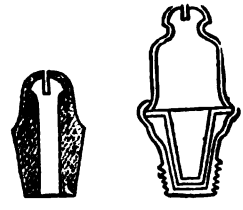
Digitized by Google

the modern steatite batswing, it is used in far greater numbers than any other burner, and is consequently answerable, to a greater extent than all other burners put together, for the very serious loss which is sustained through the depreciation of illuminating power by imperfect burners. Many gas managers are fully alive to the necessity of informing their consumers on the subject of good and bad burners, and in some places it is the practice to supply approved burners gratis. No step more desirable could be taken in this direction than the discouragement, by every practicable means, of the use of the commoner kinds of fishtail burners.

MM. Audouin and Bérard, whose researches have already been alluded to, were the first to point out the importance of a low pressure at the point of ignition in the case of flat-flame burners. As the result of their experiments with batswing burners having slits of different widths, they concluded: "That the intensity of the light increases more rapidly than the dimensions of the slit; that in comparing a burner with a slit $\frac{1}{254}$th of an inch wide with one of which the slit is $\frac{1}{58}$ of an inch, or four times as wide, it is found that with the same consumption of gas, the intensity of the lights were in the proportion of 1 to 4.1. The same quantity of gas, *when it is burned in a good burner, may, therefore, give four times the quantity of light it would do when burned in a bad burner.*" (The italics are MM. A. and B's.) "That the increase in the illuminating power takes place by a rapid diminution in the pressure, and consequently by a diminution in the speed of the flow of gas during the combustion."

As regards union jets, their conclusions were practically the same, being, that the diameter of the holes should be enlarged, so as to reduce as much as possible the pressure at the point of ignition. This reduction of pressure cannot be carried so far in the case of naked flame as in that of Argand burners, because these require some amount of pressure to enable the flame to take and retain its proper shape. The object of all improvements, however, has been to produce that which experience has shown to be the best-shaped flame, with the lowest possible pressure. A very important aid to this, as is subsequently proved, was the invention in 1860 of the hollow-top burner, Fig. 215, by Joseph and James Wadsworth. In its outward form this differs little from the batswing, its peculiarity consisting in having the head or top hollowed out, forming a chamber and causing the head to be of uniform thickness throughout. The resistance to the passage of the gas through the slit is thus equalised, and the gas consequently flows evenly through all parts of the slit, the flame being made more compact, of a better shape than that of an ordinary batswing, and of equal thickness throughout. It is, therefore, less liable to be affected by air currents; the result being an improvement in illuminating power. The advantages of this method of construction were not fully recognised until several years after its introduction, nor until the burner was made of non-conducting material in place of the sheet metal used by the inventors. Whether or not this was first done in Germany, Mr. Sugg, in 1868, produced his first steatite hollow-top batswing, Fig. 216, and since that time this burner has been extensively employed. Its superiority over previous burners of a similar kind is principally due to its being made of steatite in place of metal. Almost perfect uniformity of shape is thus secured, with non-liability to corrosion; in addition to which the non-conductivity of the material tends, as in the case of the Argand, to raise the temperature of the flame, and thus increase its luminosity. The shape of the flame has been further improved by Mr. Sugg by the use of a circular

FIG. 215.



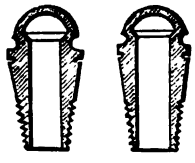
Hollow-top Batswing Burners.

Digitized by Google

saw applied from above, in cutting the slit. The ends of the slit are thus curved slightly upwards, instead of being in a horizontal line, the effect being to lessen the tendency of the gas to issue laterally from the slit and form horns to the flame.

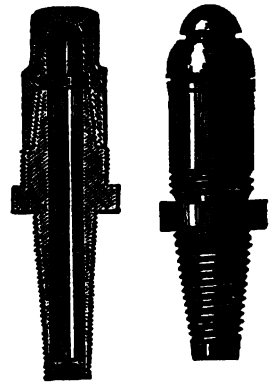
The burners introduced by Herr Brönner deserve mention as being the first flat-flame burners in which the delivery of the gas at the point of ignition was methodically controlled. Fig. 217 is an illustration of this burner, which is both larger in diameter and longer than is usual with burners of this kind. It is made of brass, surmounted by a steatite top, its lower end or inlet tapering to a small diameter, the inlet passage for the gas being contracted by means of a plug of steatite pierced with a slot of much smaller dimensions than the slit in the head of the burner.

FIG. 216.



Sugg's Steatite Hollow-top Batswing Burners

FIG. 217.



Brönner's Burners.

The object of this is to reduce the pressure of gas within the burner to just that which is necessary to steady the flame and give it shape. This burner was found by the Gas Referees in 1868 to be greatly superior to the best of the English fishtails, and only 1 per cent. inferior to the best of the English Argands at that time.

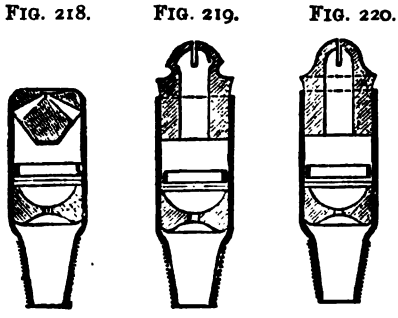
Some years ago an invention known as Scholl's platinum light perfecter attracted considerable attention. It consisted of a brass ring carrying vertically a thin plate of platinum. The ring being slipped over the top of a fishtail burner, the platinum plate was held between the two holes through which the gas issues. An obstacle being thus interposed to the flow of gas, its velocity received a check, and the jets of gas, being unable to impinge against each other in the usual way, united above the platinum plate, forming a thick and somewhat sluggish flame. With a bad burner, having very small holes and requiring a high pressure of gas, this device was very successful in increasing the light; but obviously it could have little effect with burners which already embodied in their construction the principle of reducing pressure at the point of ignition. Much the same may be said of the idea, periodically revived, of pointing two burners towards each other in an oblique direction, so as to bring the flames into contact. One fairly good burner may by this arrangement be produced out of two bad ones, but the advantage of such a proceeding is not apparent, seeing that practically the same results may be obtained from a single burner if properly constructed, and therefore at not more than one-half the cost.

Bray's flat-flame burners have been deservedly celebrated for their almost unique combination of cheapness and efficiency. In the fishtail or union jet, Fig. 218, is combined the principle of regulation or reduction of the

Digitized by Google

pressure of gas on entering the burner, with a modification of the angle of the holes through which the gas issues. Formerly the angle usually observed was about 60°, but in the "special" fishtail made by Messrs. Bray & Co. it is increased to 120°. The shape of the flame is thus much improved, its spread being ensured without recourse to more than a minimum of pressure. In the "regulator" fishtail, made by the same firm, the inlet pressure of the gas is simply checked by the insertion of a disc of fine muslin, which in the "special" burner is supplemented by a perforated plug, after the manner of Brönner's burner. As will be seen by the table of results below, burners thus constructed yield a very high result.

A still more notable advance made by this firm is in the construction of that other class of flat-flame burners of which the old iron batswing is the prototype. Fig. 220 shows their "special" batswing, or "Market" burner, and Fig. 219 their "special" "hollow top" or "slit union," the advantages of this method of construction having been early recognised and adopted by them. The tops of these burners, as well as of the "fishtails," are formed of "enamel" which is a non-corrosive and non-conducting substance discovered by Mr. Bray. In the slit union and batswing, the same means are adopted for checking the pressure of the gas at the inlet of the burner as in the "special" fishtail.



Bray's Special Burners.

The following tables, giving the results obtained with the three different types of these burners from a series of tests made by Mr. T. Fairley, Borough Analyst, Leeds, show a development in some cases fully equal to that obtained with the Standard London Argand, while at the same time they indicate a decided inferiority in the case of some of the smaller burners, especially of the "regulator" type.

Medium Lighting Power, Union Jets.

"Regulator" Burners.					"Special" Burners.				
No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.	No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.
3	0.5	3.50	6.8	9.7	3	0.5	3.43	11.3	16.4
3	1.0	4.80	6.9	7.2	3	1.0	4.90	15.6	15 8
3	1.5	6.20	7.5	6.05	3	1.5	6.03	17.6	14.6
4	0.5	4.65	12.2	13.1	4	0.5	3.73	13.3	17.8
4	1.0	6.67	14.2	10.6	4	1.0	5.15	17.4	16.9
4	1.5	8.16	14.2	8.8	4	1.5	6.57	22.4	17.1
5	0.5	5.72	17.0	14.9	5	0.5	4.80	17.6	18.3
5	1.0	7.97	20.0	12.6	5	1.0	6.67	24.4	18.3
5	1.5	9.73	21.8	11.2	5	1.5	8.30	30.0	18.2
6	0.5	5.90	18.0	15.2	6	0.5	5.48	20.1	18.3
6	1.0	8.35	23.0	13.8	6	1.0	7.65	28.4	18.6
6	1.5	10.60	28.0	13.2	6	1.5	9.20	34.2	18.7

Digitized by Google

Medium Lighting Power, Slit Unions.

"Regulator" Burners.					"Special" Burners.				
No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.	No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.
3	0.5	4.22	13.8	16 4	3	0.5	3.04	10.8	17.8
3	1.0	6.37	20.2	15.9	3	1.0	4.61	16.4	17.6
3	1.5	8.14	25.8	15.9	3	1.5	5.88	19.9	16.9
4	0.5	4.25	14.8	17.4	4	0.5	3.82	14.2	18.6
4	1.0	5.88	20.6	17.5	4	1.0	5.69	20.8	18.3
4	1.5	7.95	26.5	16.6	4	1.5	7.35	25.6	17.5
5	0.5	5.25	19.0	18.2	5	0.5	4.12	15.4	18.7
5	1.0	8.14	28.4	17.45	5	1.0	6.37	23.4	18.4
5	1.5	10.20	36.4	17.8	5	1.5	7.94	28.5	18.0
6	0.5	5 67	22.2	19.6	6	0.5	5.00	19.6	19.6
6	1.0	8.60	33.6	19.4	6	1.0	7.55	29 0	19.2
6	1.5	11.10	39.5	17.8	6	1.5	9.70	37.0	19.1

Medium Lighting Power, Batswings.

"Regulator" Burners.					"Special" Burners.				
No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.	No. of Burner.	Pressure in Inches.	Cubic Feet per Hour.	Illuminating Power in Standard Candles.	Illuminating Power per 5 Cubic Feet.
3	0.5	4.16	12.6	15.1	3	0.5	3.37	12.4	18.4
3	1.0	5.64	16.6	14.8	3	1.0	5.25	20.4	19 4
3	1.5	7.83	21.0	13.4	3	1.5	7.13	24.0	16.8
4	0.5	4.26	14.0	16.4	4	0.5	3.67	13.0	17.7
4	1.0	6.74	21.2	15.6	4	1.0	5.55	20.6	18.6
4	1.5	7.81	24.0	15.3	4	1.5	7.13	26.0	18.2
5	0.5	4.76	15.4	10.2	5	0.5	3.86	14.6	18.9
5	1.0	6.93	20.4	14.7	5	1.0	5.85	22.6	19.4
5	1.5	8.72	25.8	14.7	5	1.5	7.53	28.0	18.6
6	0.5	6.04	20.0	16.5	6	0.5	4.86	19.4	20.0
6	1.0	8.82	29.4	16.6	6	1.0	7.53	31.6	21.0
6	1.5	11.10	31.6	14.2	6	1.5	9.60	39.0	20.4

The quality of the gas operated upon averaged about 19 candles when tested with the Standard London Argand Burner.

Messrs. Bray & Co. were the first to introduce batswing burners of large size and high power, a demand for which for street lighting and other purposes was created by the advances made in electric lighting in 1878. Previous to that time, the size of flat-flame burners was practically limited to such as would consume 5 or 6 feet per hour—although there were burners in existence of a larger size—and the first attempt to outrival the electric light by the employment of gas lamps of greater brilliancy was made in the Waterloo Road under the direction of Mr. Corbet Woodall, then Engineer to the Phœnix Gas Company, with very large Argands, designed by Mr. Sugg,

Digitized by Google

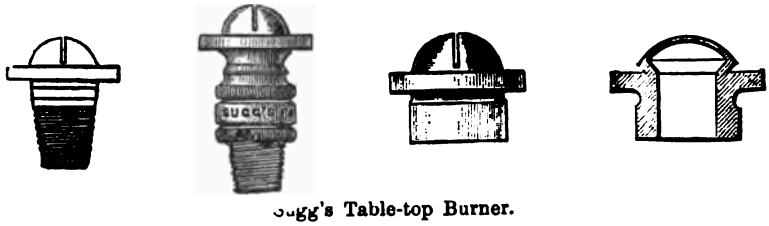
and giving the light of from 50 to 200 candles each. That these burners were a very great triumph in the art of gas illumination is unquestionable, especially having regard to the fact that substantially the same limit as to size had previously prevailed in the case of the Argand as in that of the flat flame. It was, however, foreseen that the necessity for exact regulation so as to maintain an even consumption and avoid breakages of the chimney would prove a formidable objection to the general use of Argands for such a purpose, and the development of the flat flame by the production of high-power burners of this type by Messrs. G. Bray & Co. obtained speedy and

FIG. 221.

Bray's High Power Burner.

general approval. These burners, Fig. 221, are made in various sizes, up to a very high candle-power, but it is usual to employ a medium size—say, of 30 or 40 candle-power—and group three or more together according to the light required. They are sometimes furnished with wings which take the direction of the slit, to protect the edges of the flame from the action of the air; an object which was subsequently accomplished by Mr. Sugg in his

FIG. 222.



Sugg's Table-top Burner.

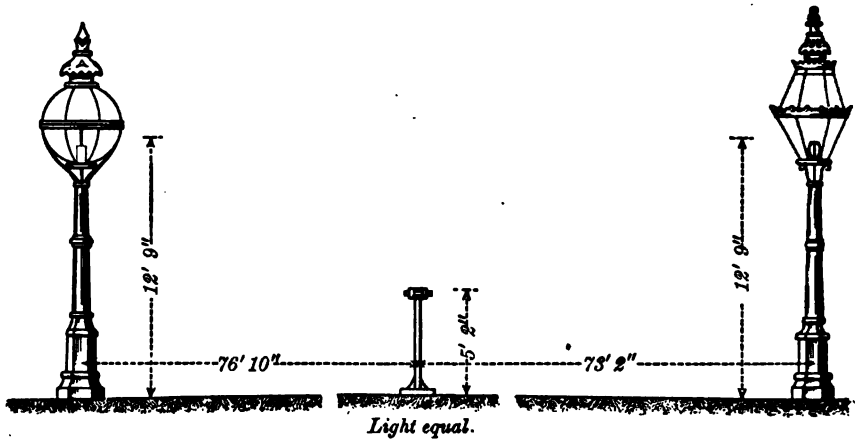
table top burner, Fig. 222, by a rim which projects from the burner immediately below the slit.

A series of exhaustive trials made at the Birmingham Gas Works during 1879-80, for the purpose of determining on the most suitable high-power burner and lantern for street lighting resulted in favour of Bray's batswing burners, grouped, with circular lantern. These trials were made by fixing the lanterns upon posts placed at suitable distances apart as shown by the accompanying illustration, Fig. 223. The consumption of gas at each lantern was accurately determined by means of separate meters previously verified, and the comparative light value ascertained by a sighting-box with disc of the usual construction mounted on a portable stand. To ensure the rays of light falling upon the disc, the two halves of the sighting-box were each placed at an angle corresponding with that formed by the line of

Digitized by Google

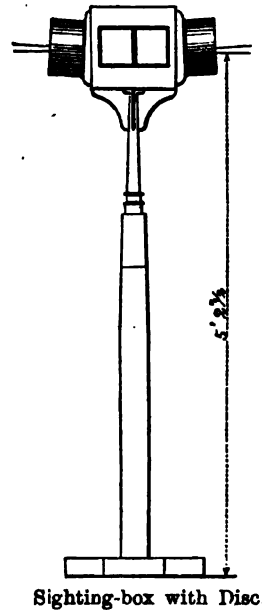
sight at a point equidistant between the two lanterns, and the height of the box, Fig. 224. A careful measurement of the distance from each of the lanterns under trial at which the shadows were equal, enabled a tolerably accurate comparison to be made of the efficiency of the various

FIG. 223.



Comparing Lamps and Burners for Street Lighting.

FIG. 224.



Sighting-box with Disc.

appliances. The experiment, the extent of which may be judged of by the accompanying table, may be said to have determined the general use of flat-flame burners for street lighting in place of Argands; and the result of the various efforts that have been made to improve the lighting of streets and other open spaces, leaves no room to doubt that coal-gas is able to hold its own against electricity for effectiveness and economy.

Digitized by Google

Description of Burners and Lanterns.

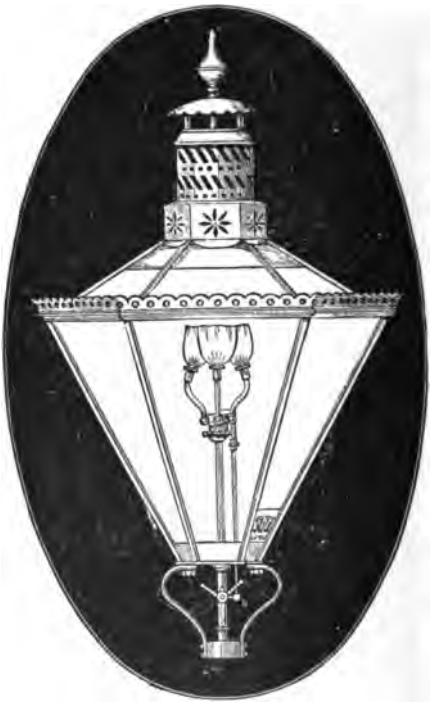
Lamp.	Description of Burner.	Description of Lantern.	Consumption of Gas. Cubic Feet per hour.	Illuminating Power in Candles. Tested with 17-Candle Gas.	Illuminating Power per foot.	Remarks.
1	Batswing	Kidd's, fitted with Reflector .	2.5 each burner	Without Reflector, 4 62 each	1.85	In direct line with Reflectors, 54.4 candles.
2	„	Collin's Patent „ . .	6.0 „ „	„ „ 16 90 „	2.80	
3	„	Ordinary Street	5.0 „ „	„ „ 14.00 „	2.80	
4	Sugg's, 80 Candle Argand . . .	Sugg's Shadowless . . .	22.8 „ „	„ „ 74.55 „	3.26	
5	Bray's, 60 „ Triple Batswing .	3 Frosted Globes, 24-in. diameter	26.4 each globe	„ „ 85.00 „	3.21	These globes diminish the light by 35 per cent.
6	„ „ „ „ „ .	3 Clear „ „ „	24.0 „ „	„ „ 73.00 „	3.04	
7	Sugg's, 100 „ Argand . . .	3 Opal Top „ 30-in. „	27.0 „ „	„ „ 101.70 „	3.77	
8	„ 80 „ „	1 „ „ 26-in. „	23.4 „ „	„ „ 79.87 „	3.41	
9	„ 200 „ „	„ „	45.6 „ „	„ „ 180.20 „	3.95	
10	Bray's „ „ Quadruple Batswing	Bray's Shadowless . . .	44.4 „ „	„ „ 134.40 „	3.02	
11	„ 60 „ Triple „	„ „ . . .	21.6 „ „	„ „ 63.00 „	2.92	
12	Burner and Lantern used by the Rue du Quatre	Paris Gas Company, in the Septembre	48.0 „ „	„ „ 139.40 „	2.90	
13	Gaudet's, Paris	Gaudet's	52.8 „ „	„ „ 158.10 „	2.99	
14	Mallet's, „	Mallet's	43.0 „ „	„ „ 141.10 „	3.28	
15	Wigham's	Wigham's	60.0 „ „	„ „ 150.0 „	2.50	
16	Sugg's 200 Candle, Hollow Top, Flat Flame	Sugg's Octagon	66.0 „ „	„ „ 201.00 „	3.04	A better result—viz. 3.24—was obtained with a consumption of 45 cubic feet per hour.
17	Sugg's 100 Candle Argand . . .	„ „ (New pattern) .	30.60 „ „	„ „ 96.15 „	3.14	
18	Bray's Quadruple	24-in. Circular				
19	„ 400 Candle	Bray's				

Digitized by Google

Figs. 225, and 226 give illustrations of Sugg's and Bray's street lanterns.

In Bray's lantern the air for combustion of the gas is admitted at the bottom, through a bed of small tubes, for the purpose of preventing any sudden inrush of air. The products of combustion escape through the top of the lantern, the openings in which are so arranged as to enable the discharge to be continuous during all weathers. The lantern is, in fact, storm-proof, and the gas burns with a steady flame, fed by a slowly moving up-current of warm air. In Sugg's lantern the air is admitted at the top, and circulates through the lantern to the gas flame—the products of com-

FIG. 225.



Sugg's Street Lantern.

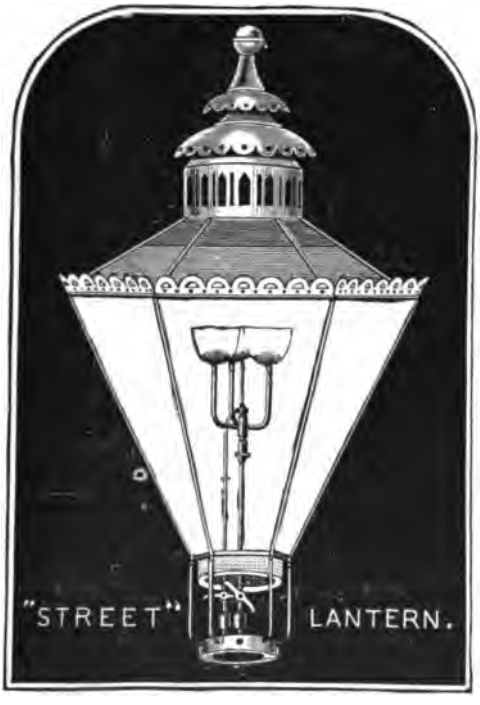
bustion being discharged also at the top through a centre opening in the reflector, to which is attached a tube communicating with the exterior. In both lanterns the tops are frequently glazed either wholly or in part with opal glass for the purpose of reflecting the light downwards, and at the same time avoiding any distinct shadow upon the upper portions of the surrounding buildings. Various modifications of these lanterns are in general use.

Governor Burners.—It has been seen that due limitation of the air supply is all-important for the full development of the illuminating power of coal-gas. The reason for this is not far to seek. Common coal-gas as delivered to the burners is composed of many distinct gases—mostly combustible—of which nearly $\frac{1}{2}\frac{0}{0}$ths are either non-luminous or only feebly so. These consist mainly of free hydrogen (usually in the proportion of nearly one-half), light carburetted hydrogen or marsh gas, and carbonic oxide; whilst the olefines and the members of the benzene series, which are the light-

Digitized by Google

giving constituents, form only from 3 or 4 to 6 per cent. of the total volume. It is this great preponderance of non-illuminating gases which makes it so difficult to effect perfect luminous development, because their combustion has to be provided for as well as that of the illuminating gases, and a flame so composed is most easily affected by an excessive air supply. It follows that the poorer the gas is in illuminating constituents, the lower should be the pressure at the point of ignition. We are indeed confronted on all sides with the necessity of keeping down the pressure to the lowest point consistent with the proper combustion of the gas. In the best constructed burners, as has been seen, means are provided for reducing

FIG. 226.



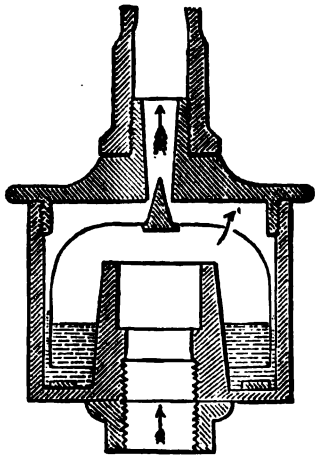
Bray's Street Lantern.

the pressure within the burner, but their efficiency is in a great measure dependent on the amount, and also on the constancy, of the initial pressure. The latter cannot, from various causes, be relied upon, the pressure in the mains being liable to fluctuations due to the weather and other circumstances. It is, moreover, impossible to maintain equal pressures in the mains throughout the whole area of a district, owing to variations of level; and since a difference of only a few tenths is a matter of considerable importance in the economy of gas lighting, various contrivances, called governors or regulators, have been introduced for the purpose of meeting the difficulty by maintaining, under all practical conditions of inlet pressure, a uniform pressure within the burner, and consequently at the point of ignition. For many years small "dry" governors, the invention of Mr. W. Sugg, working on the same principle as the water governor (p. 169), but in place of the water having a flexible leather diaphragm, have been used for controlling

Digitized by Google

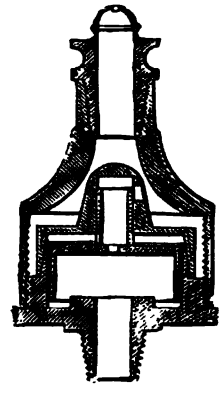
the quantity of gas consumed in the street lanterns. These instruments are fixed immediately underneath the burner, within the lantern, and are so adjusted as to deliver, with the same burner, a constant quantity of gas under all conditions of inlet pressure. They are fairly trustworthy for the purpose intended, although the tendency of the leather diaphragm to become less flexible seriously militates against their efficiency for any considerable length of time. But their size renders them unsuitable for indoor use, on account of the shadow they would throw from a bracket or chandelier; whilst for street lighting a more perfect substitute has been desired. One of the earliest that offered was "Giroud's" rheometer, or "flow measurer," Fig. 227, although this appears to have been in a great measure anticipated by the invention of Mr. John Leslie in 1841. The rheometer is from its size adapted alike for indoor and street lighting. It is in reality a

FIG. 227.



Giroud's Rheometer.

FIG. 228.



Sugg's Christiania Burner with Steatite Float Governor.

governor of volume, because, unlike the lamp governor above referred to, its action is independent of the size of the burner, which may be replaced by others without affecting the rate of delivery through the instrument. As will be seen from the figure, the light metallic bell, which is contained in a metal cylinder and sealed with glycerine, is pierced with a hole for the passage of the gas, and surmounted by a conical valve, working in the outlet at the top of the cylinder. The inlet for the gas is at the bottom, and over the opening at the top is placed the burner. The gas on entering the bell causes it to rise, and at the same time passes through the hole to the valve at the outlet, and so to the burner. As the valve opens or closes according to the pressure within the bell, it follows that there must be pressure on both sides of the latter, the reacting pressure above preventing the entire closing of the valve, and thus permitting the required quantity of gas to pass to the burner.

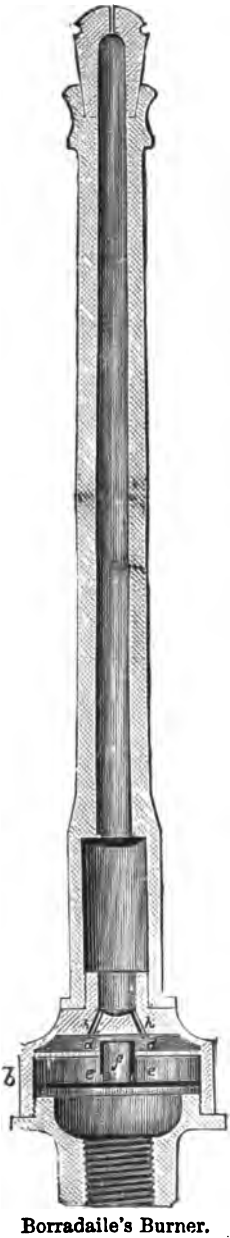
Sugg's Christiania burner governor is an adaptation of the street lamp regulator already mentioned; but his steatite float governor is similar in principle to the rheometer. Fig. 228 shows an adaptation of this governor for domestic lighting.

Borradaile's governor, Fig. 229, is a simple and trustworthy instrument, adapted equally for street and domestic lighting. In its most usual form it consists of a light metal disc fitting accurately within a metal cylinder, and

Digitized by Google

surmounted with a short tube, which passes through the centre of a fixed metal plate in the upper part of the cylinder, and works up and down

FIG. 229.

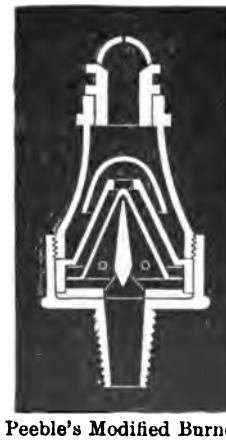


Borradaile's Burner.

FIG. 230.

Peeble's Needle Governor Burner.

FIG. 231.



Peeble's Modified Burner.

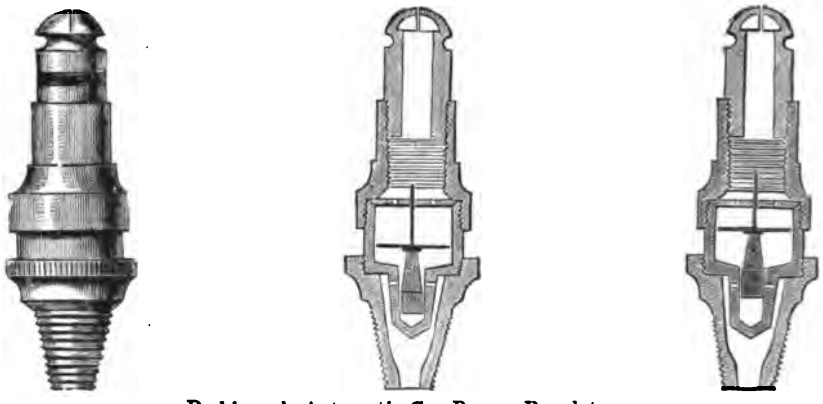
according to the pressure of gas upon the disc. The gas flows to the outlet through small holes in the sides of the tube, and as this is lifted or lowered by the rise and fall of the disc, the gas passage between the top of the tube

Digitized by Google

and the outlet becomes smaller or larger, the delivery of gas through the governor remaining constant.

Peeble's needle governor burner, Fig. 230, is similar in principle to Giroud's rheometer, but possesses the merit of dispensing with the use of liquid, and is, notwithstanding, a very efficient instrument. It is thus described by the late Dr. W. Wallace: "In a little cylinder stands a so-called needle, on the point of which rests a flanged cone of exceedingly thin metal. At one side of the cylinder there is a small tube leading away the gas, and the orifice of which is influenced in area by the action of the cone. The instrument, by means of a screw leading into the side tube, can be made to deliver any desired number of cubic feet, which it does with surprising accuracy, provided that the pressure of the gas is not less than $\frac{6}{10}$ths of an inch." Dr. Wallace adds: "In trials that I have made, I have not found the variations of volume at different pressures to exceed

FIG. 232. FIG. 233. FIG. 234.



Parkinson's Automatic Gas Burner Regulator.

1 per cent." Fig. 231 shows an adaptation of this governor for indoor lighting.

Another very efficient instrument of this class is the "Automatic Gas-burner Regulator" invented by G. J. Parkinson This (Figs. 232, 233, and 234) is a very compact regulator, and well adapted for indoor lighting. It consists of a very thin disc of metal, fitting loosely in a metal cylinder, and having suspended from it a small conical-shaped valve which rises and falls according to the motion of the disc, within a kind of socket, pierced at the upper part with holes for the passage of the gas. The gas having passed the valve, rises to the outlet through the small annular space between the cylinder and the disc, entering the burner by means of perforations in the top of the cylinder. The motion of the disc is steadied by a guide wire passing through the top of the cylinder.

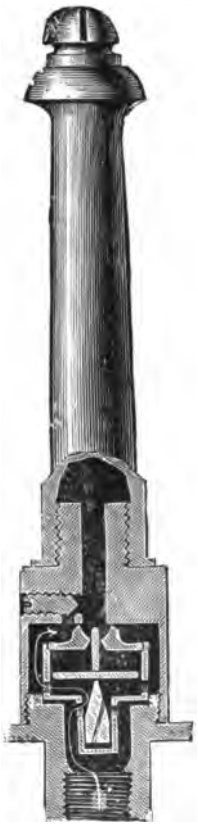
The variations of this governor burner at different pressures are very slight, and its performance is very satisfactory. A modification of it is used for street lamp regulation (Fig. 235).

Messrs. G. Orme and Co. also manufacture a very satisfactory regulator suitable for both classes of lighting. This is from a patent taken out by Behl. Figs. 236 and 237 show section and elevation of the street lamp regulator, and Fig. 238 its adaptation to indoor lighting. In Fig. 239 is shown a suspension regulator constructed on the same principle. This is for use with large burners, and is inserted in the descending supply-pipe of the apparatus.

Digitized by Google

Consumers are frequently urged—and generally by interested parties—to employ a governor or regulator fixed at the outlet of the meter, with the object of reducing the pressure and regulating the supply to the whole of the premises from a single point. There are many kinds of such governors, but as they do not usually vary in principle from the ordinary gas governor, it is not necessary to describe them fully. In cases where the action of these instruments is understood and the fittings are in good order, and more

FIG. 235.



Parkinson's Street Lamp Regulator.

FIG. 236

Section.

FIG. 237.

Elevation.

Orme's Regulator.

particularly where the pressure of gas is, owing to the district being upon a high level, necessarily more than sufficient, their use may be attended with benefit to the consumer, who should find that by keeping down the pressure exerted at the meter his consumption is reduced. Their indiscriminate use is, however, greatly to be deprecated, for they too frequently become, not only a source of embarrassment to the gas undertaking, from the complaints of insufficient supply to which they give rise, but also of inconvenience to the consumer, whose fittings, probably, are not in the best of order, and who cannot always be brought to understand why he is worse off for gas after having called to his aid one of these economisers. A very little reflection, however, will make it apparent why this mode of regulating is not uniformly

Digitized by Google

advisable, or to be generally recommended. The fittings of a dwelling-house, for example, are frequently added to from time to time. Now it is an extra burner that is wanted; at another time a gas fire is introduced; and again, probably, cooking by gas is found to be—as many people do find it—indispensable. Thus the supply-pipes, which at the time they were put in were probably fully adequate, become in course of time unequally, and perhaps over, taxed. Moreover, the natural tendency of gas is to ascend, because it is lighter than air, so that there is an increase of pressure to the extent of $\frac{1}{10}$th of an inch for every ten feet rise in height. The upper rooms of a house, consequently, have always the best chance of being well lighted. Conceive, now, of a case in which the supply pipes have become so fully taxed as to require the fullest pressure that can be exerted from the mains to give a sufficient supply to all parts of the premises. The very worst thing that can be done is to throttle the pressure at the meter, which

FIG. 238.

Orme's Regulator.

FIG. 239.

Orme's Suspension Regulator.

is the function of these governors; because by doing so one only saves gas by going without it. At one part or other of the premises the supply must be deficient. On the other hand, the very best thing to do is to take advantage of the pressure afforded from the mains, and get the gas conveyed through the fittings to where it is required to be used, and then regulate the pressure. The most rational method of controlling pressure, from a consumer's point of view, and one that cannot fail to give satisfaction, is the use of regulator burners. By employing these throughout, an equal and adequate supply may be secured in every room of the house, the gas will be consumed to the best advantage, and the gas bills will be quite as pleasant to contemplate as though the pressure at the meter had been kept down to the lowest practicable limit.

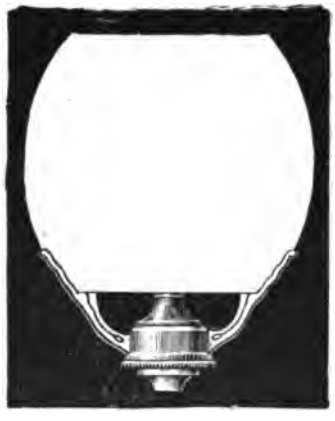
Globes.—Glass globes, when used, should always have wide openings both at top and bottom, as in Fig. 240, which shows Sugg's Christiania globe and governor burner. These ensure a steady atmosphere for the flame, and secure it against the cooling effect of a sharp draught of air, such as is experienced when the openings are narrow.

An ingenious method of increasing the illuminating power of gas flames when enclosed in globes or shades was patented by Mr. R. O. Gardner in 1889. In describing his invention at a meeting of the Glasgow Philosophical Society (Dec. 18th, 1889), Mr. Gardner stated that he was led up to the

Digitized by Google

invention by his experiences in connection with the consumption of smoke in boiler furnaces. Many years ago, after having been summoned for creating an alleged nuisance by smoke, he investigated the principle of consuming, or rather of preventing, smoke; and he found that highly heated air, properly applied in the furnace, was all that was necessary. He studiously avoided the method in which other inventors had carried out the principle of regeneration in gas-lamps, and was led to supply the air from the bottom of the shade alone, and to control the draught by means of a damper at the top of the funnel, which, by being screwed up or down, adapted the lamp for burning gas of any quality or at any pressure. In like manner he carried out the same principle in ordinary gas globes or shades. He discovered that, by materially diminishing the outlet, the flame considerably increased in size. His thoughts were at once directed towards the materials and form best suited for a cover to the shade. Asbestos was tried, by moulding or fitting it on the globe, but when a high temperature

FIG. 240.



Sugg's Christiania Globe and Governor Burner.

was maintained, the globes would occasionally crack. Latterly, after making various attempts to overcome this and other difficulties, he hit upon the expedient of using small plates of mica between the asbestos and the glass shade as non-conductors of heat. Although he had subjected the shades to very severe tests, he had not since broken one. Figs. 241 and 242 are from the drawings which accompany the complete specification, and the following is a description of the cover finally adopted by the inventor. Sheet asbestos, specially prepared for the purpose, is cut into discs varying from 4 up to $7\frac{3}{4}$ inches in diameter, and rising $\frac{1}{4}$ inch to each size so as to suit all the different sizes of shades. In order to hold the cover in its place three asbestos studs are fixed on its lower surface, moving in an eccentric, which allows the cover to be most perfectly fitted. Round the lower edge there are half a dozen discs of mica fixed. These act as non-conductors between the glass shade and the cover. In the centre of the cover there is punched out an opening $1\frac{3}{4}$ inches in diameter; and the disc so removed is fixed by means of a stud to the cover at one side of the opening on which it turns, thus becoming a valve to regulate the size of the aperture according to the quality and quantity of gas used.

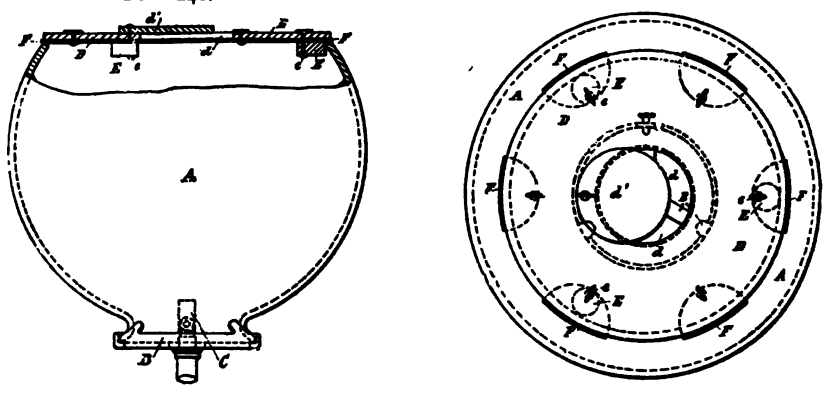
The results of tests made with covered and uncovered shades and open

Digitized by Google

flames, with Glasgow gas consumed in a union jet, showed an improvement due to the covers, when tested in a horizontal line, of from 10.36 per cent. to 29.27 per cent., over open flames, and over uncovered shades of from 17.12 to 43 62 per cent. At an angle of 45°, the superiority of the covered shades was even more marked, the results showing a difference in their favour of from 53.76 to 120.5 per cent.

In principle, if not actually, this invention was anticipated by a patent

FIG. 241.



Gardner's Globe.

applied for in 1886 by A. P. Ker and F. S. Green. The drawings accompanying the complete specification of this patent, Figs. 243 to 247, show the application of the invention to ordinary glass shades and also the chimneys of Argand burners, not only in their construction, but also, if preferred, by means of a removable collar or inverted conical-shaped cover, as in B, Fig. 244, and E, Fig. 246; made of glass, asbestos, fireclay, talc, or other suitable refractory material. No means are provided for regulating the

FIG. 243. FIG. 244.

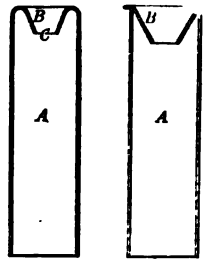
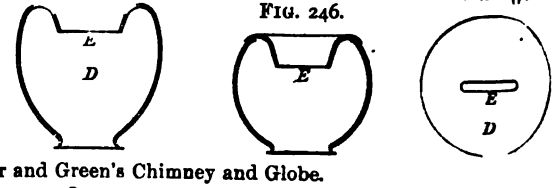


FIG. 245. FIG. 246. FIG. 247.



Ker and Green's Chimney and Globe.

opening for effluent gases, as in the case of Gardner's, but the patentees claim that by proportioning the size of this to the quantity and quality of the gas or oil to be consumed, "the heated gases arising from the lighted gas or oil are deflected towards the burner, where in consequence of the increased heat the combustion becomes more perfect, thus producing an exceedingly white and brilliant light, at a reduced expenditure of illuminating material."

This arrangement is stated to give very excellent results as regards increase of illuminating power, with both kinds of burners, the development

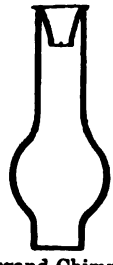
Digitized by Google

of light being increased by from 30 to 57 per cent. With Argand burners, however, a chimney of special shape resembling the chimney of an oil lamp, Fig. 248, has been adopted by the patentees.

A patent was taken out in 1888 by Mr. John Methven for (1) the application to apparatus for producing light from which the external air is excluded, of a dried air supply obtained by forcing air through or over quicklime or other suitable desiccating material, as and for the purpose set forth; and (2) controlling the supply to lamps of air which has been dried by forcing it through or over a desiccating material, whereby a constant standard of light is obtained, irrespective of barometric and thermometric conditions.

The hygrometric state of the atmosphere varies from hour to hour, and the presence, under ordinary circumstances, of water vapour in the air which is intended to support combustion, reduces the photometric value of the same. The patentee states that the production of light in lamps, lanterns, and other apparatus from the combustion of coal or other gas or vapour, &c., is greatly improved by the use of dried air to support combustion. The amount of light given will be constant, as it will be independent of the varying hygrometric conditions of the atmosphere, so that a light supplied with dry air is especially useful for photometric purposes. In addition to the air, the combustible material may, if desired, be also dried, the effect of which will be to further increase the illuminating power of the flame.

FIG. 248.



Argand Chimney.

In order to effect the dericcation of the air, the patentee employs power to force it over or through the desiccating material. The power may be derived from a small fan; or the air may be drawn through the material by a suitable pump. The desiccating of the air may take place in an apparatus similar to a gas purifier, the air entering the vessel near the bottom, and after passing through the desiccating material escaping at the top. Or the trays to carry the desiccating material may be so arranged that the air shall pass in a circuitous path over the material, in which case it is preferable that the air shall enter at the top and pass out at the bottom of the vessel. The drying of the gas or other vapour may be effected by passing it through similar apparatus.

Of the many hygroscopic materials which may be employed, the patentee prefers to use quicklime broken up into small pieces and placed on the trays. Experiments have demonstrated that one cubic foot of this material will suffice to remove the aqueous vapour from about 50,000 cubic feet of air, and as coal gas requires, to induce proper combustion, from six to ten times its volume of air, according to the style of burner used, it follows that one cubic foot of lime will dry air sufficient for the combustion of from 5000 to 8000 cubic feet of gas. The same quantity of lime will also serve to dry 50,000 cubic feet of gas or other combustible vapour.

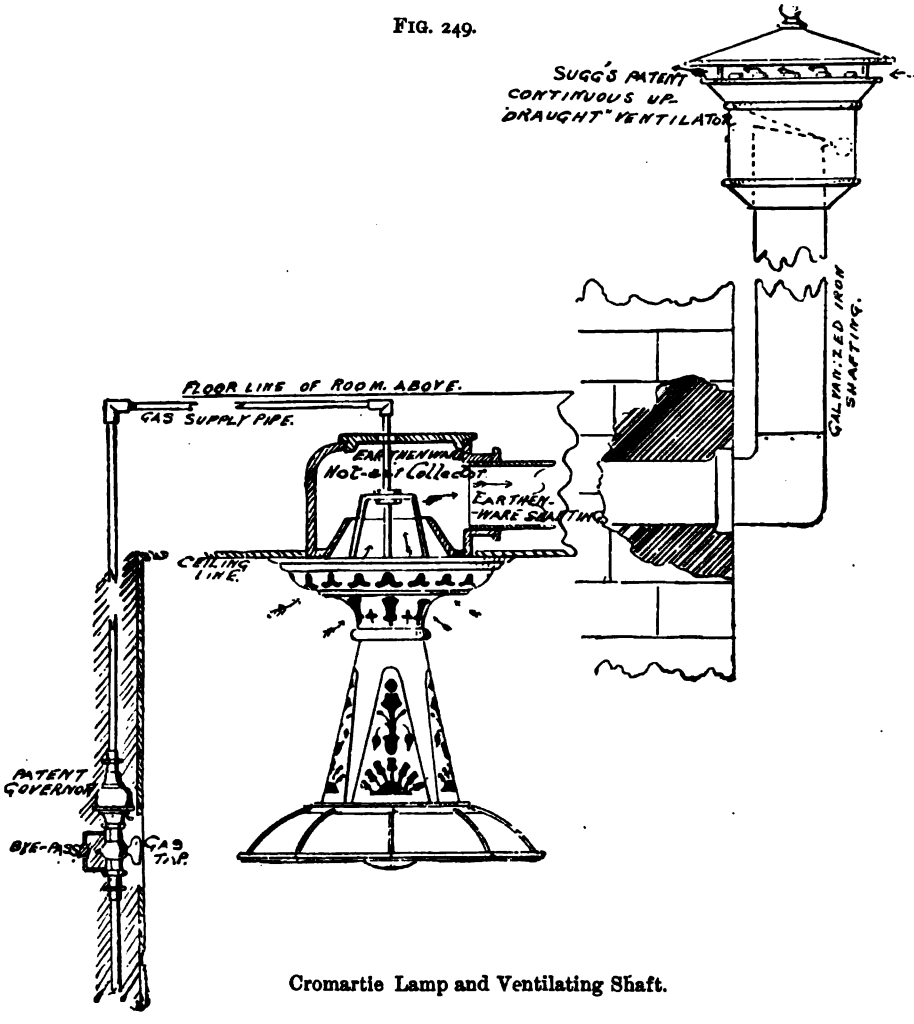
The apparatus used for burning the illuminant must be so arranged that the external undried air cannot come into contact with the flame. Thus, supposing the apparatus to consist of an Argand burner, the bottom of the chimney will be hermetically sealed against the entrance of external air, and will be in connection with a pipe for the supply of the artificially dried air. This pipe is provided with a cock, so that the delivery of the air may be controlled according to the barometrical and thermometrical conditions of the atmosphere for the time being. The object of having this control for the desiccated air supply to the flame is, that a sufficient quantity of air may be always supplied to ensure perfect combustion, and to prevent access to the

Digitized by Google

flame of more air than is absolutely necessary (according to the barometric and thermometric conditions) for that purpose.

It is clear that what the patentee had chiefly in view was to obtain a more constant standard of light for photometric purposes, but in the "Journal of Gas Lighting," vol. lii. p. 672, is described an adaptation of this method by Messrs.

FIG. 249.



Cromartie Lamp and Ventilating Shaft.

Methven and Sugg for the construction of a combined system of lighting and ventilation. It is there stated that, according to Mr. Methven's experiments, drying the air will improve the illuminating power of gas flames burnt in it by from 10 to 15 per cent. The air is delivered to the point of combustion at a very little above the ordinary atmospheric pressure by a pair of alternating bellows worked slowly by a water meter, an arrangement which is very suitable for general shop or warehouse use. It may of course be obtained in other ways, as by a fan driven by a steam or gas engine. The arrangement is automatic, the motor being stopped when the lamps are turned off, and started again when they are lighted up. A large Cromartie

Digitized by Google

lamp, Fig. 259 (p. 289), gives a most brilliant light with a consumption of 20 cubic feet of gas per hour, the duty being after the rate of 11·37 candles per cubic foot when burning with undried air. Supposing the improvement of light due to the drying of the air to be only 10 per cent., this lamp would give a duty of 12.50 candles per cubic foot. As, however, carbonic acid as well as moisture are arrested by the Methven system, it would probably be safe to say that, with such a large lamp as the above, the improvement would be at least 15 per cent. on an average, which would raise its duty to 13.06 candles per cubic foot with nominally 16-candle gas. This the "Journal of Gas Lighting" believed to be an unparalleled result. Air is supplied to these burners at the rate of 10 cubic feet to the cubic foot of gas. It should be remarked that one essential point in the success of these experiments has been the governing of the air as well as the gas at the point of combustion.

In a valuable and exhaustive paper on Photometry, read by Mr. Methven at a meeting of the Southern District Association of Gas Managers, November 14, 1889, the author related the results of experiments made by him on the influence of aqueous vapour on flames of different burners. These were intended as a contribution to the science of photometry, but inasmuch as they have a direct bearing on the development of illuminating power, the following quotation from the paper will not be out of place:—

"The diagram, Fig. 250, in which the ordinates represent the temperature of the air supply to the burners, and the abscissæ the illuminating power in candles, shows the effect produced by supplying flames with dry and saturated air at a constant rate. The lines marked A, show the development of illuminating power from a flame consuming 5 cubic feet per hour in a Sugg's 'London' Argand, when supplied alternately with dried and saturated air. The dotted line represents the dry air supply, and the black one the saturated air supply. It will be observed, when dried air is supplied to the flame, the light therefrom is practically of constant quality; but when a saturated air is supplied with increasing temperature, the light value is rapidly diminished. Thus, we have, between the temperatures of 50° and 75°, a loss of 10 per cent. of light value from the 5-feet flame. The lines marked B represent the results produced from the same cause on a flat-flame burner consuming a fixed rate of 5 cubic feet per hour within a globe. With dried air supplied to the globe, a constant value of light results at all temperatures; but with a saturated supply the light value diminishes as in the former case. Between the temperatures of 50° and 75°, 11.2 per cent. loss of light occurs. The lines marked C represent the effect produced on a flame of ordinary gas 2½ inches in length consumed with a chimney from a Harcourt's pentane standard burner. With dry air supplied to the flame, the light was absolutely constant; but when a saturated air was supplied, loss of light, increasing with the temperature, was the result. Between the temperatures of 50° and 75°, the reduction of light value was 13 per cent. Within the ranges of temperature which I have selected as being possible—changes which may occur in any testing place—there is a marked increase in the loss of light between the experiments A, B, and C. This I believe to be due to the powers of the different lights to battle with the aqueous vapour with which the air was charged.

"In carrying out the above experiments, I arranged an apparatus which made provision for dispensing with the forced, or controlled, supply of air, and permitted the burner to induct its natural air supply. The lines D on Fig. 250 represent the development of light from a 5-feet flame in an Argand burner supplied with its natural supply of air. The amount of air inducted by the burner under these conditions was ascertained after each experiment, by closing the large port and attaching the tube conveying the

Digitized by Google

controlled supply of air. The rate of air was then adjusted so as to attain the same development of light from the flame, which was at all times burning at a rate of 5 cubic feet per hour. It was found that, as the temperature increased with dried air, the burner inducted a larger volume of air. Thus at the temperature of 66°, the illuminating power of the flame was 15.4 candles, and the volume of air was found to be at the rate of 34.26 cubic feet per hour. At 85°, the light was reduced to 15.1 candles; while the air supply was found to be equal to 37.62 cubic feet per hour. In-

FIG. 250.

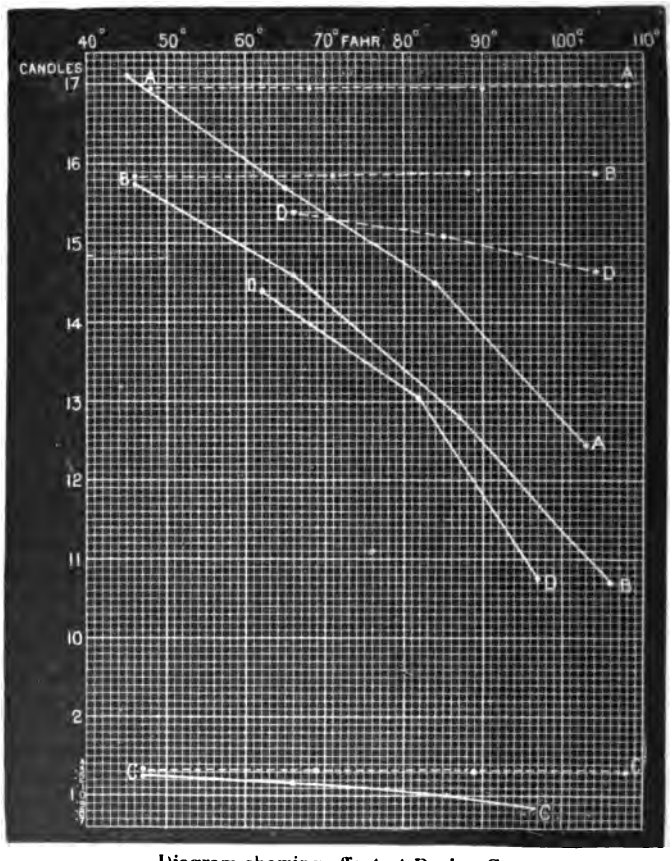


Diagram showing effect of Drying Gas.

creasing the temperature to 104°, the light was reduced to 14.7 candles; while the air supply was found to be 39 cubic feet per hour. When the air supply was saturated, very nearly the same increased volume was inducted by the burner, with a similar reduction in the development of light, as with the other saturated air experiments. It was evident, however, in the last experiment, that if a constant light was desired, a constant volume of air must be supplied to the flame within the chimney."

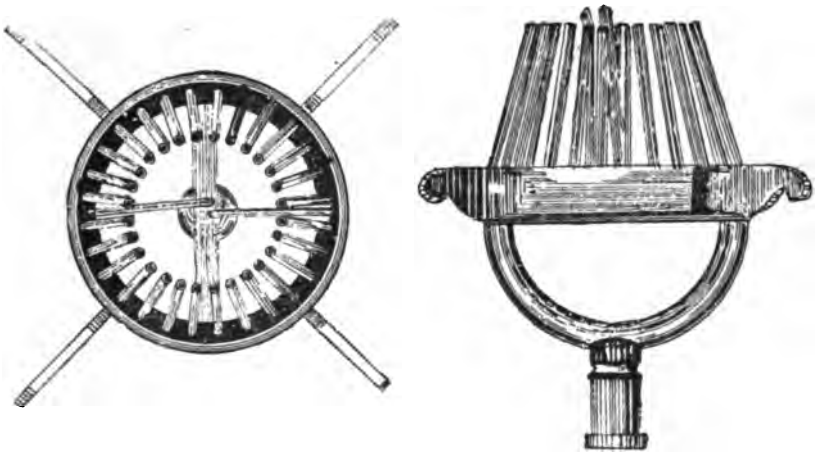
In the same paper Mr. Methven describes some experiments showing that the light from a flame consuming 5 cubic feet per hour developed less light as the rate of air increased. In the case of dry air, with an increase of 48.8 per cent. of air, the decrease of light was 20 per cent., or, in other

Digitized by Google

words, a decrease of illuminating power equal to 0.076 candle for every 1 per cent. added to the air supply. In the case of the saturated air supply there was a very similar reduction of light with an increased air supply—50 6 per cent. of increase in the air supply resulted in a decrease of illuminating power of 21 3 per cent., or a decrease of 0.071 candle per 1 per cent. of increase of air supply. These experiments, says Mr. Methven, are useful in showing quantitatively the effect produced by increasing or decreasing the supply of air to Argand burners. In substituting chimneys of various sizes, the amount of air inducted by each might be arrived at by determining the light value of the flames.

Regenerator Burners.—An idea at one time prevailed, that an increase of illuminating power was obtained by heating the gas prior to combustion, and experiments made at Munich seemed to bear out this view An Argand burner was also designed by Mr. Leslie, Fig. 251, with the object of raising the temperature of the gas by passing it through a number

FIG. 251.



Leslie's Argand Burner

of small brass or copper tubes fixed in a gallery corresponding to the hollow cylinder of an ordinary Argand, and converging towards the top. These tubes become heated by the gas flame, and a portion of this heat is taken up by the gas in its passage through the burner, while the rest is lost by radiation. The flame, therefore, loses in temperature to some extent, and the good results obtained are more correctly to be attributed to the large area of the gas openings, which allowed of the gas being consumed under a very low pressure. The Leslie burner, moreover, was proved to be inferior to the Sugg-Letheby burner, the top of which is made of non-conducting material; whilst experiments have shown a decrease of one candle in the results obtained with a Sugg's London Argand, when constructed wholly of metal, instead of the top being formed of steatite.

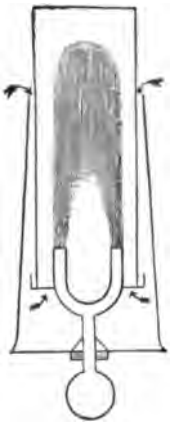
The subject of the Munich experiments was fully dealt with by the Gas Referees in their Report presented to the Board of Trade in 1871, and experiments made under their direction were quoted as disproving the assumption that the illuminating power is influenced by the temperature of the gas. Neither raising nor lowering the temperature had any effect on

Digitized by Google

the illuminating power of the gas, which remained practically the same under variations extending from 32° to 296° F.

It is, however, far otherwise when heat is applied to the air for supporting combustion, and the application of this principle constitutes one of the most remarkable of modern developments of the art of gas illumination. The origin of the idea—as also of that of regenerative furnaces—can undoubtedly be traced to the invention of the "hot-blast," which effected so great an economy in iron manufacture. An attempt was made to apply the principle to gas-burners as far back as the year 1835, when a patent was taken out by Chaussenot for "heating the cold air required to supply the burner, by means of the flame itself—that is to say, an Argand burner should be fitted up with two or even three glass chimneys, one within the other, and so arranged that the cold air must pass between the outer chimneys and inner one, before it reaches the flame. The air will thus be heated previous to its reaching the burner, and will thereby produce a better combustion of gas." In the year 1854, the Rev. W. R. Bowditch produced his regenerative gas-burner, Fig. 252, which, as will be seen from the illustration, embodied Chaussenot's invention, but consisted of two glass chimneys, in place of three, as employed by the latter. It is stated that the air supply was heated by this arrangement to 500° or 600° F., and Dr. Letheby obtained with it an increase of 67 per cent. of illuminating power. This burner, however, was not suitable for general employment. The inner chimney could not be made to withstand the great heat to which it was subjected; and in addition the increased effect was speedily neutralised by the cloud or film which formed upon the surface of the glass. Moreover, the results obtained by Dr. Letheby were with cannel gas, probably of 24 candle-power, whilst with common gas he stated that he did not find a like increase of illuminating power. Having regard to this admission, and to the probability that the result obtained with cannel gas was due in a great measure to the larger q antity of air required for the combustion of such gas than for that of common gas, it was pertinently observed by Mr. R. H. Patterson in his article on Gas-burners, &c. (King's "Treatise on Coal Gas"), that "it would be utterly unsafe to accept 67 per cent. as a normal result, Mr. Bowditch's estimated gain of 35 per cent. being doubtless nearer the truth.* According to the same authority, "the first successful application, in a practical form, of heating the air and gas for illuminating purposes was made by Mr. Wigham, notably in his large triform and quadriform burners for lighthouses." However this may be, it is undoubtedly to Mr. Frederick Siemens that the credit is due of producing the first burner in which the principle of regenerative heating, or recuperation, is applied in a form suitable for general employment. Figs. 253 and 254 show this burner in the form in which, after many experiments and modifications, it was eventually introduced in 1879, and the succeeding years. Fig. 253 is an

FIG. 252.



Bowditch's Regenerative Burner.

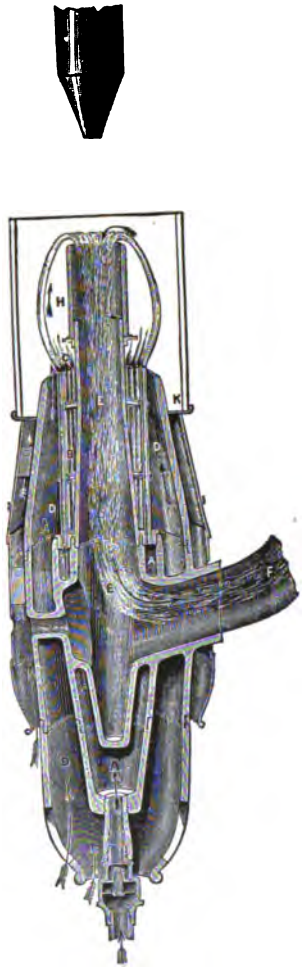
* In 1882, Messrs. H. Green and Sons exhibited at the Crystal Palace Electric and Gas Exhibition a double-chimney Argand burner, which was reported by the examiners to yield, when tested in a horizontal direction, 3.63 candles per cubic foot of gas consumed.

Digitized by Google

elevation, and Fig. 254 a section, of the combustion chamber, forming the lower portion of the burner, by the arrangement of which the products of combustion are caused to impart heat to the gas and air, during the passage of the latter to the point of ignition; the actual flame temperature not being drawn upon to produce this effect. The burner is thus described by the inventor:—

FIG. 253.

FIG. 254.



Siemens' Regenerative Burner.

The burner is composed as follows:—

A—Gas-chamber supplying the gas tubes, B.
C—Exit for the gas supplying the flame.
D—Air-chamber.
E—Regenerative heating-chamber.
F—Suction-chimney leading to chimney G.

"The gas in a cold state passes through the gas-chamber A, and gas tubes B to the point of ignition C.

Digitized by Google

"Cold air enters the air-chamber D, and before arriving at C is equalised and well distributed to the flame by means of a toothed circular collar.

"The flame burns around the porcelain H, and turning over the top of it descends into the interior of the burner or regenerative heating-chamber E.

"This effect is produced by a continuous current occasioned by the main chimney G and branch or suction-chimney F.

"The waste heat and products of the flame being thus collected in the regenerative heating-chamber E, the temperature of the latter is raised to about 900° C.

"The consequence is that the gas and air in the surrounding chambers (during the progress of their ascent from the bottom to the top of the burner) are raised to a similar temperature, thus increasing the illuminating power.

"Outside the burner is a jacket of thin metal, I, between which and the burner a current of cooler air ascends to prevent the overheating of the burner, and also to add to the supply of the air to the flame.

FIG. 255

Siemens' Flat-flame Burner.

"On the top of this outer casing rests a cylinder of glass, K, which protects the flame from the action of the wind."

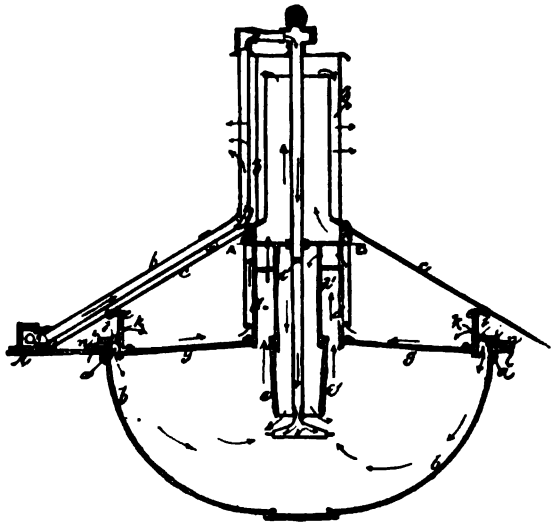
This burner gives an intense white light, equal to from 5 to 6 candles and upwards per cubic foot of gas consumed, when tested horizontally, as compared with about $3\frac{1}{4}$ candles yielded by the same gas with the Standard Argand burner. It will be apparent, however, that its great size constitutes a grave objection to its general employment: and great care is necessary to secure proper regulation of both air and gas supply. In these respects it must be admitted that the original Siemens burner did not completely fulfil the requirements of a practical appliance for gas illumination; but it possessed the very great merit of having been the first approach to a practical exposition of the value of the regenerative system as applied to the luminous development of gas flames, and thus indicated the direction in which a notable improvement was to be achieved.

Fig. 255 shows an adaptation of the system by Mr. Siemens to burners of the flat-flame type. It is stated to give very good results, especially with rich, or cannel, gas. Its shape is seen to be quite different from that of the original burner, and resembling closely some of the many adaptations of the

Digitized by Google

system by other inventors whom the success of the new departure soon stimulated into activity. One of the earliest of these—if not the earliest—was Clark's burner, Fig. 256, the patent for which was taken out in 1881. This, as will be seen from the illustration, consists of a lamp body fitted with a semi-globular glass *b*, and containing the concentric tubes *d*, *d'*, *e* and *e'*. The connection between the outer tube and the lamp body is made with the reflector plate *g*. The gas supply pipe *t*, is led up one side of the lamp to the top of the chimney, and descends in the centre thereof to the burner *v*, which may be an inverted Argand, or other suitable form. The air for maintaining combustion enters in the first place through holes in the lamp body at *k*, and passes upwards between the tube *d* and an outer screen to the cross tubes shown, whence it descends in the interior of the pipe *d'* to

FIG. 256.



Clark's Burner.

the burner. The products of combustion rise between the tubes *d* and *d'*, and in their exit part with some of their heat to the entering air, retaining sufficient warmth, however, to keep up a draught in the chimney, and carry off the water of combustion through the holes in the wind-guard *z*. Air can be admitted at *h* between the reflector and the glass, to keep the latter cool, if so required. In a street lamp upon this model the actual burner is roughly made of an ordinary Argand with the steatite removed to make an annular slot.

Grimston's burner, Figs. 257 and 258, brought out almost at the same time, is very similar in construction, but the regenerative arrangement consists of a number of vertical tubes contained in a cylinder, up which the products of combustion pass to the chimney. The cylinder is concentric to an inner cylinder containing the gas-supply tubes, the outer cylinder being traversed by the air which is required to be heated on its way to the burner, and in order that the products of combustion may more completely give up their heat to the air, the cylinder is intersected by strips of wire gauze, passing around and between the tubes. The air thus becomes highly heated, and, being brought into contact with the small tubes which convey the

Digitized by Google

gas to the point of ignition, gives up some of its heat to the latter. Both air and gas are thus raised in temperature prior to combustion.

Both the burners above described, although identical in principle, are in their arrangement essentially different from the original Siemens, and superior to it in practical efficiency. With the Siemens burner the

FIG. 257.

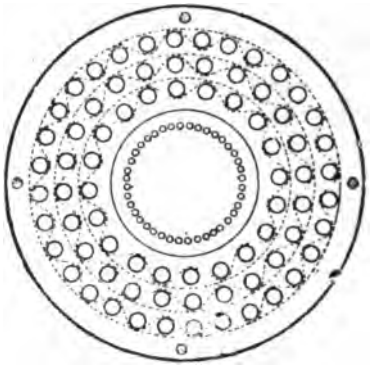
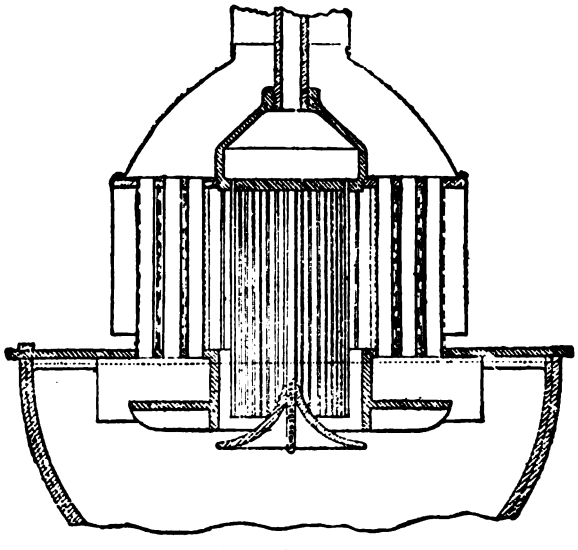


FIG. 258.



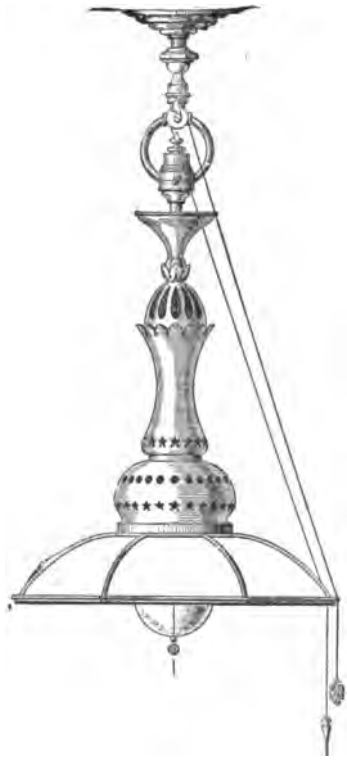
Grimston's Burner.

objectionable shadow thrown down by the combustion chamber had to be overcome by a powerful reflector placed in a suitable position above the flame; whereas in the new type of burner this shadow was avoided by directing the flow of gas downwards, thus causing the flame to spread outwards in a horizontal direction, forming a continuous sheet or ring. The reflector *g*, Fig. 256, with which the burner is furnished, is consequently brought into use as a supplement to the flame, and greatly adds to the efficiency of the burner. As to the duty afforded by each, Messrs. Dibdin and Foster reported that a small Clark's burner consuming 5 feet per hour at

Digitized by Google

the Crystal Palace gave a high initial duty, with a very moderate consumption. Tested horizontally, it yielded 4.76 candles per cubic foot; and vertically, with the disc at an angle of 45°, 6.91 candles. Of the Grimston burners, the larger sizes appeared to give the best results, although when tested horizontally the mean duty was not high. A burner consuming 25 cubic feet per hour yielded 3.96 candles per cubic foot consumed when tested horizontally, but this was increased to 8.56 candles when tested vertically, and with the disc at an angle of 45°. These tests were made with common or 16-candle gas.

FIG. 259.



Sugg s Cromartie Burner.

In rapid succession to these burners have followed many others, embodying the principle of recuperation, but differing in detail, and also in efficiency. Of these, perhaps the most prominent are the Cromartie, the Wenham, and the Schulke.

The Cromartie is the invention of Mr. D. W. Sugg, and is supplied by the manufacturers, Messrs. W. Sugg & Co., Limited, in almost every conceivable variety of design, suitable for all purposes of domestic and general lighting. Fig. 259 shows one adaptation of it for a dining-room or library, and this is capable of modification so as to form a ventilating light (Fig. 249, p. 280). It is stated to yield, when tested vertically, as much as 18 candles per cubic foot of gas consumed, but this must be largely due to the reflector.

The Wenham burner is also made in a great variety of forms, and is

Digitized by Google

very extensively used. Fig. 260 shows a section of the burner, while Fig. 261 is a ventilating light, showing arrangement of flues for carrying away the products of combustion. These burners were certified by the late Mr. F. W. Hartley as capable of affording a light, in a vertical direction, of upwards of 16 candles per cubic foot of gas consumed. Much of this, again, is due to the reflector, the light yielded, when tested at an angle of 45°, being reduced by about one-third.

Fig. 262 shows Schulke's lamp in section. It is seen to consist of two ordinary flat-flame burners, enclosed in an elongated glass globe suspended from a lamp body, the regenerative arrangement being of the simplest kind. The direction taken by the air supply on entering the lamp, and by

FIG. 260.

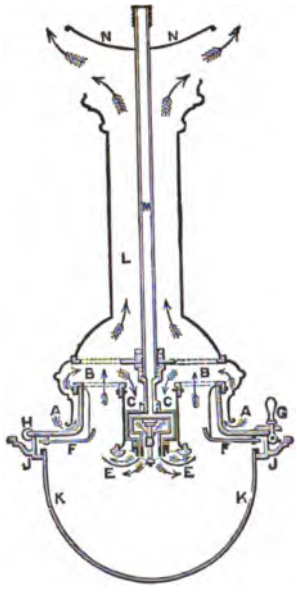
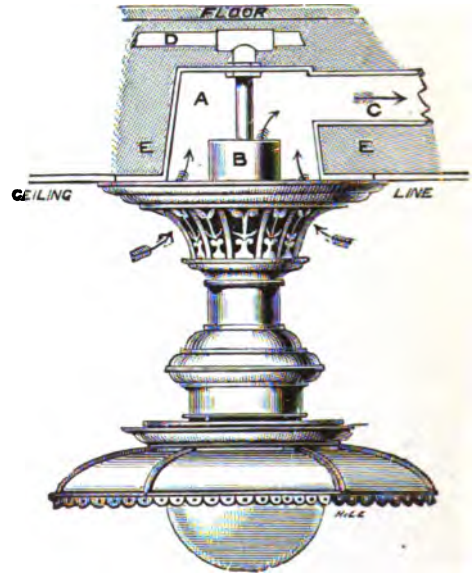


FIG. 261.



Wenham Burner.

the products of combustion on their way to the chimney, are shown by the arrows. It is claimed for this lamp that it is not affected by draughts, burning as well in exposed positions as in a room; and it is stated to be highly economical in gas consumption. Fig. 263 shows one of its applications for street-lighting purposes.

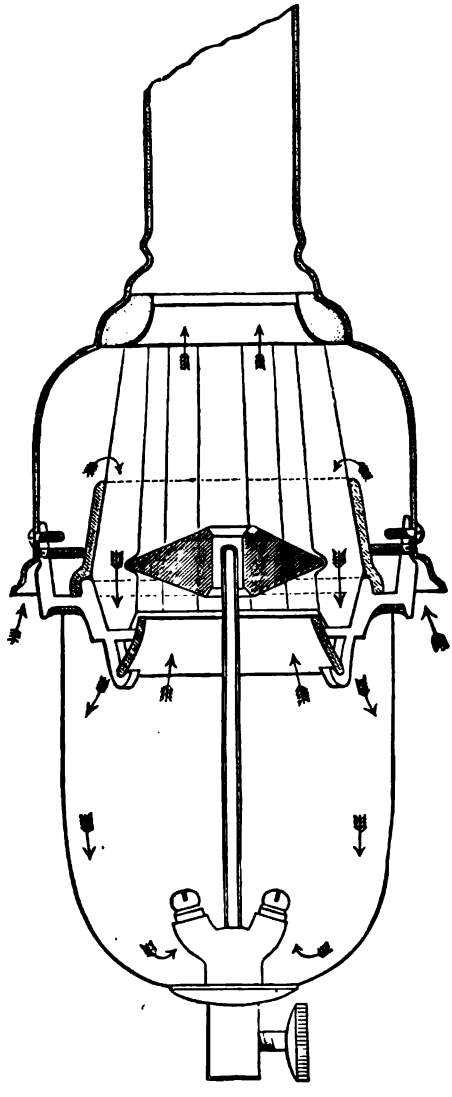
Reference has been made in the foregoing to ventilating lights, with regard to which it may be observed that an objection commonly urged against the use of coal-gas is that its combustion vitiates the atmosphere of rooms. Not only may this objection be completely overcome by the adoption of an arrangement such as is shown in Fig. 261, in which the products of combustion are led away through a flue suitably constructed between the ceiling and floor above, but thorough ventilation can be secured by the agency of gas, provided the means be properly applied. The combustion of the gas induces an upward current of air, which is further promoted by the stream of heated air and products passing away through the flue, so that, with efficient regulation, it is possible to change the atmosphere of a room as often as desired, by means which are capable of being applied to almost every modern dwelling-house. The two arrows rising from the ceiling level

Digitized by Google

in Fig. 261 show an outward current of air drawn from the interior of the room, and independent of the products of combustion which are discharged from the pipe B, as shown by the single arrow.

Sunburners, such as are commonly employed for lighting public buildings,

FIG. 262.



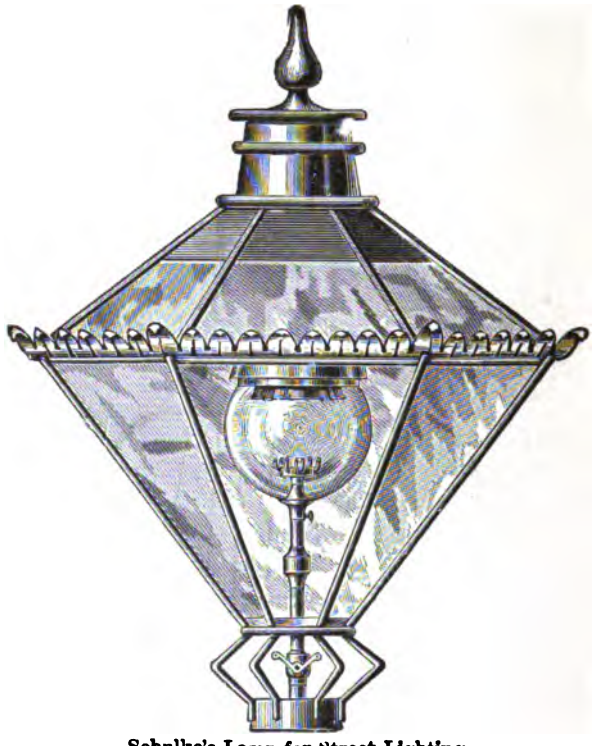
Schulke's Lamp.

are very powerful aids to ventilation, in addition to being an efficient means of illumination, inasmuch as they are invariably connected to an up-shaft or flue communicating with the exterior of the building. The products of combustion are thus discharged into the outer air, together with a considerable proportion of vitiated air from the interior. The atmosphere of a

Digitized by Google

crowded gas-lighted room, therefore, even if its temperature be somewhat high, may be far more endurable than that of one which is lighted, for

FIG. 263.



Schulke's Lamp for Street Lighting.

FIG. 264.

Strode's Sunlight.

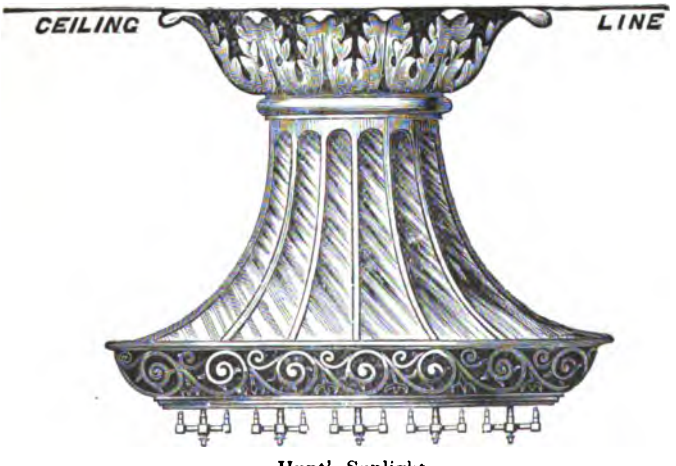
example, by electricity, which does not vitiate the air, but is incapable of promoting its circulation, and therefore necessitates special arrangements for

Digitized by Google

ventilation. The reason for this is simply that in the latter case the carbonic acid of the breath will accumulate in the absence of efficient ventilation, whereas the use of gas in the manner described ensures the removal of a considerable proportion of the vitiated air. The not unfrequent

FIG. 265.

FIG. 266.



Hunt's Sunlight.

use of gas-lights in or near to the ceiling of a hall lighted by electricity is thus explained.

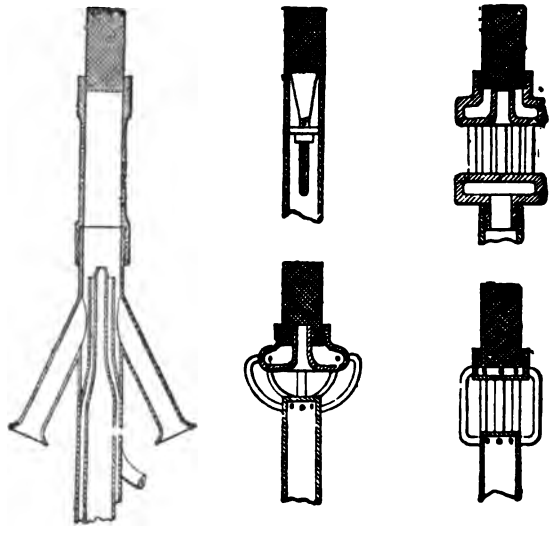
Fig. 264 shows Strode's Sunlight, which has been very generally employed. Figs. 265 and 266 show plan and elevation of Hunt's Improved Sunlight. This is a combination of hexagonal reflectors, arranged as shown in Fig. 265, by which a very large reflecting surface is obtained; and their arrangement admits of the employment, in a vertical position, of the best types of flat-flame burners. A brilliant and steady illumination is thus secured; the

Digitized by Google

general effect being very pleasing, with, it is stated, a decided economy in gas consumption.

Incandescent Burners.—Since coal-gas consists so largely of gases which are non-luminous, but at the same time capable of giving a high temperature—namely, hydrogen, marsh gas, and carbonic oxide, producing a flame temperature which is estimated to exceed 2000° F.—it is not surprising that inquiry should be directed to the utilisation of this heat as a means for producing a higher illuminating power from the gas than can be obtained when it is consumed in the ordinary way. The idea of incandescent burners is not by any means a new one. Many years ago, Gillard proposed to render water-gas luminous by burning it in contact with a solid substance, such as metallic platinum, which, in the form of a wire-work cap, being heated to whiteness

FIG. 267. FIG. 268.



Lewis's Burners.

by the flame, evolves light. This proposal, only with the substitution of coal-gas for water-gas, has been almost exactly reproduced during recent years by Lewis, whose burner, which was shown at the Crystal Palace Electric and Gas Exhibition in 1883, is thus described by the Examiners, Messrs. Dibden and Foster: "The Lewis burner is usually in the form of a rectangular cylinder which is always made of fine platinum wire, fixed on the extremity of an open pipe. The mixture of gas and air is burnt within the platinum cylinder, causing the incandescence of the metal. Judging from the appearance of the burner when in use, and the known properties of platinum in promoting oxidation, at high temperatures, the combustion of the gas is perfect. The air supply to the burner is under a pressure of 14 inches of water. Advantage is taken of this high pressure, and consequent great velocity of the air escaping in the nozzle of the burner, whereby a further supply of air is drawn by 'induction' from the external air through the lateral open pipes."

Figs. 267 and 268 show various forms of this burner, the light produced by which is stated to be so perfect that the colours of textile fabrics show as well by it as by daylight. It is also unaffected by wind, maintaining perfect

Digitized by Google

steadiness under all conditions of weather. The average duty afforded by this burner is stated in the report of Messrs. Dibden and Foster to be 4.63 candles per cubic foot of gas consumed, when tested in a horizontal line.

The Clamond incandescent lamp, Figs. 269 and 270, exhibited at the same time, also required an air supply under a pressure of about 6 inches of water, but this has since been dispensed with, and an improved form of lamp substituted, Fig. 271. It consists of a conical basket made of

FIG. 269.

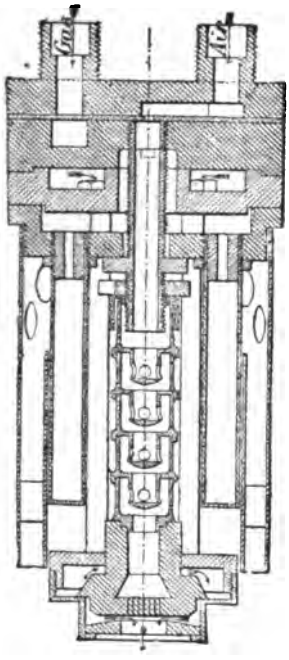
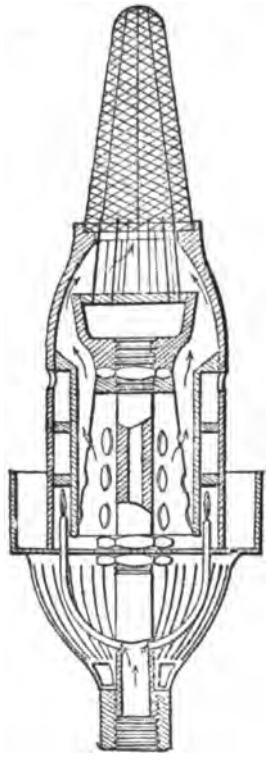
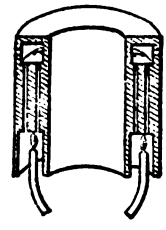


FIG. 270.





Clamond Incandescent Lamp.

twisted threads of calcined magnesia. When used as an inverted burner a cage composed of a few thin platinum wires supports the basket. The manufacture of these magnesia baskets is extremely ingenious. They are made from a mixture of the hydrate and acetate of magnesium, brought into the condition of a paste or cream by means of water. After they are made from this material on a suitable mould, they are dried and fired. The acetate and hydrate are decomposed with loss of carbon and water and become converted into the oxide. Such baskets are said to be produced very cheaply; but are extremely fragile. In both forms of this burner the air supply is heated by means of auxiliary burners in the interior of the apparatus, notwithstanding which, the duty achieved by the more complete one exhibited at the Crystal Palace is stated to have been not more than 4.26 candles per cubic foot consumed, when tested in a horizontal line. The baskets are stated to last from 50 to 60 hours before requiring renewal.

Digitized by Google

A more recent invention of the same class, is that of C. Auer von Welsbach, patented in 1885-7. This is an instance of research work of apparently only theoretical importance, unexpectedly proving of great practical value. As the result of his investigations of the rare metals, Welsbach showed in 1885 that it was possible by fractionating the nitrate to cleave didymium, hitherto considered to be an element, into two metals which he named neo- and praseo-dymium. In the same year he brought out his first patent, in which it is stated that his invention relates to the manufacture of an illuminating appliance, in the form of a cap, or hood, to be rendered incandescent by gas and other burners, so as to enhance their

FIG. 271.

Improved Clamond Lamp.

illuminating power. For this purpose, a mixture of oxide of lanthanum and zirconium, or of these with oxide of yttrium, is employed. The proportions in which the substances are used may be varied within certain limits; very suitable proportions being: 60 per cent. of zirconia or oxide of zirconium; 20 per cent. of oxide of lanthanum and 20 per cent. of oxide of yttrium. The oxide of yttrium may, however, be dispensed with; the composition then being 50 per cent. of oxide of lanthanum, and 50 per cent. of zirconia. Instead of using the oxide of yttrium, ytterite earth, and instead of oxide of lanthanum, cerite earth containing no didymium and but little cerium, may be employed.

For applying the substances mentioned a fine fabric, preferably of cotton previously cleansed by washing with hydrochloric acid, is used. This fabric is saturated with an aqueous solution of nitrate or acetate of the oxides, and gently pressed until it does not readily yield fluid, so that in stretching or opening out the fabric the fluid does not fill up its meshes. This fabric is then exposed to ammonia gas; and, when it has been dried, it is cut into

Digitized by Google

strips and folded into plaits. One method of giving the desired shape to the cap or hood is to draw fine platinum wire through the meshes of the net, and bend it to the form of a ring, so as to give the fabric the shape of a tube, the edges of which are then sewn together with an impregnated thread. The cap or hood thus formed is supported on cross wires in the chimney of the lamp. On igniting the flame, the fabric is quickly reduced to ashes; the residuum of earthy matter, nevertheless, retaining the form of the cap or mantle.

A further patent, taken out during 1886, describes other substances which may be used for forming the mantle; and a second patent in the same year relates to the treatment of the earths of the rarer metals—chiefly belonging to the aluminium and calcium groups—in order to obtain

FIG. 272.

SECTION OF THE BURNER

FIG. 273.

Welsbach Burner and Mantle.

therefrom solutions suitable for the production of incandescent substances such as those described in the former patents.

In a subsequent patent, dated 1887, a method is described of regenerating the mantles of incandescence bodies, by first providing them with an additional coating of the salt solution of the rare metals, or compounds thereof, and then subjecting them to heat so as to convert the coating into an oxide of the metal. Also subjecting the mantles, when so coated, to an atmosphere either of ammonia vapour or of the vapour of oxalic acid or benzoic acid, in order to convert the coating into a gum-like cohering mass for the purpose set forth. According to the patentee, experiments made with the process show that a mantle which had been burning for 150 hours in a very dusty atmosphere, gave a measured light of 8¾ normal candles. After regeneration, the mantle gave, under otherwise the same conditions, a light of 18 candles.

Fig. 272 is a section of the burner, which is in effect a Bunsen burner, serving to mix the gas with air in such a way that the gas at the mouth of the burner is stated to be mixed with from 50 to 60 per cent. of air, admitted

Digitized by Google

through a perforated disc at the base. Each burner is fitted with a regulator or governor, so as to cause the consumption of gas to remain constant, under all variations of pressure. The flame produced by the mixture of gas and air gives no light, but sufficient heat to make the mantles incandescent.

The mantle, Fig. 273, prepared as already described, is suspended from a clay ring fixed to an iron rod over the flame of the Bunsen burner, the chimney is put over it to produce the requisite draught, and in this manner it is stated the mantle will burn over one thousand hours without much decrease of light. The gas passes through the regulator at the rate of about 2½ cubic feet per hour, and mixing with the air in the body, B, Fig. 272, of the burner produces a flame of 2½ to 3 inches high. This flame

FIG. 274.

Welsbach Lamp complete.

brings the mantle to a white heat, and causes it to throw out a brilliant, soft, steady light, stated to be of from 25 to 50 candle-power.

Fig. 274 shows the lamp complete when lighted. The light is of excellent quality, and the form of the lamp renders it applicable to almost all situations. The objection, however, to the fragility of the mantle has yet to be overcome.

The following tests, made under the direction of the author, with one of the burners illustrated above, show a most favourable result as regards illuminating power. The regulation of this burner, however, was evidently faulty, since the rate of consumption increased with every increase made in the pressure.

Test of the Welsbach Incandescent Burner.

Quality of gas = 3.4 candles per foot according to Standard Argand.

Pressure in Tenths.	Consumption. Feet.	Illuminating Power in Candles.	Candles per Foot.
4.0	2.45	15.7	6.41
5.0	2.85	19.8	6.94
6.0	3.15	22.0	6.98
7.5	3.6	23.7	6 58
10 0	4.0	23.0	5.75
16.0	4.6	22.0	4.78

Considerable improvement in the durability of the mantle, its light-

Digitized by Google

giving power, and also in the construction of the burner, have since been made, as shown in the illustrations below.

FIG. 275.

Welsbach "C" Burner with Governor.

FIG. 276.

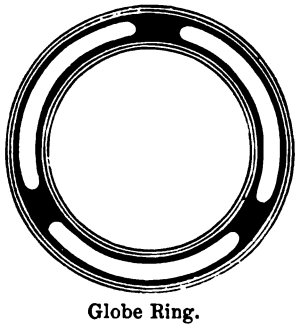
Gallery.

FIG. 277.

Mantle Rod.

Fig. 275 represents the "C" burner complete, with governor, mantle and chimney, and is adjusted to burn $3\frac{1}{2}$ cubic feet of gas at one-inch pressure. The parts of which this burner is composed are shown separately in the figures

FIG. 278.



Globe Ring.

FIG. 279.

Bunsen Tube.

FIG. 280.

Nipple.

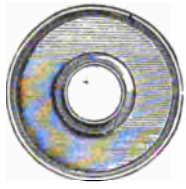
next following. Fig. 276 is the "gallery" in the top of which fits Fig. 277, the central "mantle-rod" of fire-clay, which has a long cylindrical stem, with a fork at the upper end to carry the mantle. On the outside of the gallery, when a globe is to be used, is placed Fig. 278, the "globe ring."

Digitized by Google

Fig. 279 is the "Bunsen tube," into which is screwed the "nipple" perforated with holes, through which the gas enters the lower part of the Bunsen tube, to mingle with air entering by the lateral openings. Over the Bunsen tube is fitted Fig. 281, the "lighting back plate," to prevent the flame "lighting back" at the nipple. In order to suit all kinds of fittings the "adapter" is provided, the upper end of which is screwed to fit the Bunsen tube, while the lower has a tapering screw.

In Fig. 283 is shown the same burner with the addition of a bye-pass,

FIG. 281.



Lighting Back Plate.

FIG. 282.

Adapter.

FIG. 283.

"C" Burner with Bye-Pass.

FIG. 284.

Mantle.

by means of which a small pilot jet is kept burning within the mantle, while the Bunsen burner is turned off. This gives the convenience and economy of being able at any moment to turn on the full light when required, while at other times an inappreciable volume of gas is consumed, but enough light is shown to indicate the position of the burner. It also tends to prolong the life of the mantle, as there is no shock or explosion in the chimney when the light is turned up. Fig. 284 shows the more recent form of the "mantle," which is gathered to a smaller circumference at the top and fitted with a kind of loop which rests in the fork of the mantle-rod. Such mantles are said to be prepared without being subjected to the action of ammonia, as were the earlier ones, and consequently to be more durable. For convenience of transport they are dipped, after burning, in a solution of collodion which upon drying forms a protective covering. This

Digitized by Google

covering requires to be burnt off after placing the mantle in the position in which it is to be used.

Later tests with improved burners and mantles have given results as high as 16.6 candles per one cubic foot of Birmingham gas. Much, however, depends upon the gas and air being mixed in such proportions as will produce the hottest flame. Thus the substitution of a globe in place of the usual chimney may cause an enormous depreciation in the luminosity, owing to an insufficent quantity of air being supplied to the flame. Burners have, therefore, been invented—the Bandsept, Denayrouze, &c.—for use with the incandescent mantle, which have for their object the production of a more intimate and more properly proportioned mixture of gas and air than can be obtained with the ordinary Bunsen burner. The luminosity of the mantle is considerably increased by the use of these burners.

FIG. 285.

Denayrouze Burners in clusters.

FIG. 286.

FIG. 287.

Bandsept Burner.

The original Denayrouze burner was provided with a mixing chamber in which the proper amount of air and gas was intimately mixed by the aid of a small electro-motor. In a later form of the apparatus the electro-motor was dispensed with, the mixture being effected by the aid of a turbine worked by the heated products of combustion rising from the burner. A still simpler form has now been introduced (Patent No. 1777, January 22, 1897), in which mechanical aid for mixing the air and gas is dispensed with. The gas passes by means of several Bunsen tubes into a mixing chamber the top of which is covered with wire gauze, and through the centre of this chamber a tube open below to the atmosphere is passed.

The glass chimney rests upon a closed gallery, so that the chimney draught not only assists the gas pressure in obtaining the necessary amount of gas for proper combustion, but also induces a current through the central air-tube, which, expanding upon reaching the base of the flame, directs the latter against the sides of the mantle. In still later forms the chimney is dispensed with, and this simplification renders it easy to arrange these burners in groups or clusters, as shown in Figs. 285 and 286.

Digitized by Google

The Bandsept burner is of simpler construction, the gas issuing from a special injector nozzle, and in its passage upwards inducting the necessary quantity of air through ports placed at different heights.

The burner is enlarged at the top and is covered with wire gauze (Fig. 287).

Mr. E. C. Sayer, Borough Gas Examiner, Ipswich,* has obtained the following results when using these burners:

Burner.	Consumption. Cubic feet per hour.	Illuminating Power. Candles.	Candles per cubic foot of gas used.
London Argand	5	15	3
Welsbach	3¾	50	13·3
Denayrouze	9	150	16.6
Bandsept	5	120	24

A new burner, the invention of M. Kern, of Paris, has lately been introduced by the Incandescent Gas Light Company which, although not capable of affording more illumination per cubic foot of gas consumed than other burners which have been previously brought forward, yet possesses great advantages.

In previous burners the consumption of gas has been from 3½ to 6 cubic feet per hour, and any increase or decrease in the consumption of gas by these burners has been accompanied by a more than proportionate decrease in the light emitted per cubic foot consumed. Indeed, in many cases an increase in the consumption of gas has been accompanied by a decrease in the luminosity of the mantle, which has quickly been spoiled by the deposition of carbon upon it.

The Kern burner, however, is capable of burning more gas than that for which it is regulated (which may happen upon changes in pressure in the mains taking place) without losing in efficiency—developing from the increased consumption a proportionate increase in luminosity. The burner also may be constructed in sizes capable of burning only 2 cubic feet or even 1 cubic foot of gas per hour without loss in efficiency. The great advantages of such burners will be readily seen by those who have been in large rooms previously lighted by a chandelier with several batswing burners, and which are now lighted by an incandescent burner either fitted on one of the arms of the chandelier or, if this has been removed, attached to a small pendant hanging from the centre of the ceiling.

Although the one incandescent burner may give as much light as three or more batswings which it has replaced, the effect is far from pleasant, and the new burners may be employed in lighting such rooms much more effectively and at the same time with equal economy.

The burner is illustrated by Fig. 288, *A* is the nozzle at which the gas enters the Bunsen tube, *CC* being holes for the admission of air, which may be regulated by means of the usual throttle ring. The tube *B* consists of two cone frusta, the upper one inverted. The lower or mixing cone is made of such a length as to give a thorough and self-burning mixture of gas and air; whilst the length of the upper cone may be about twice as long. Although the length of the upper cone may be considerably varied without diminishing the efficiency of the burner, it is most important that the angle of divergence of the cone should be maintained between 5° and 7°. The cones are surmounted by a mixing chamber consisting of two cylinders, the

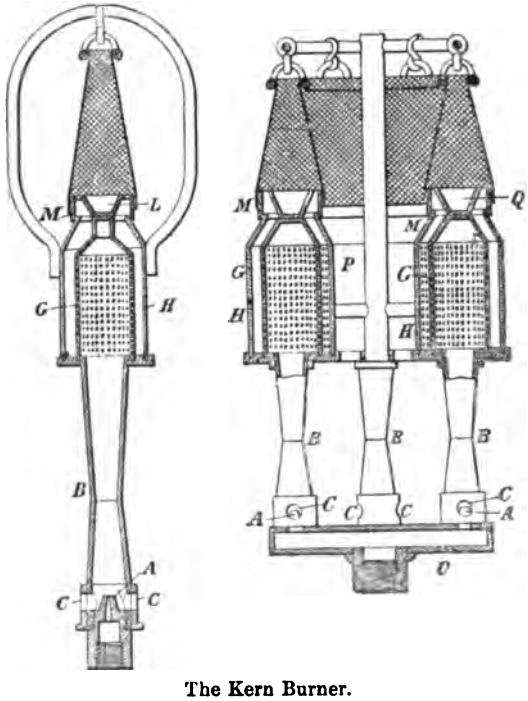
* Jour. Gas Lighting, 1807, lxx. 794.

Digitized by Google

inner one of which is perforated; and to the top of these is attached a nozzle *LM*, by means of which the mixture of gas and air is diverted against the sides of the mantle suspended above. Fig. 289 shows a means of employing a number of these burners in the form of a cluster, arranged with an annular mixing chamber of two concentric mantles enclosing between them an annular space. On account of a perfect self-burning mixture of gas and air being obtained by the burner chimneys may be dispensed with.

Street lighting with incandescent burners is rapidly growing in favour. In the early nineties, when the system was first tried in this country, much difficulty was experienced owing to the fragility of the mantle and con-

FIG. 288. FIG. 289.



The Kern Burner.

sequent breakage due to the vibration caused by the traffic. Antivibration burners were introduced to overcome this defect—the burner being suspended by a coiled spring—and these have given very favourable results.

The cost of street lighting by incandescence appears to be very little, if any, more than that which obtains in the case of lighting with the ordinary flat-flame burners, though the amount of light is increased about fourfold.

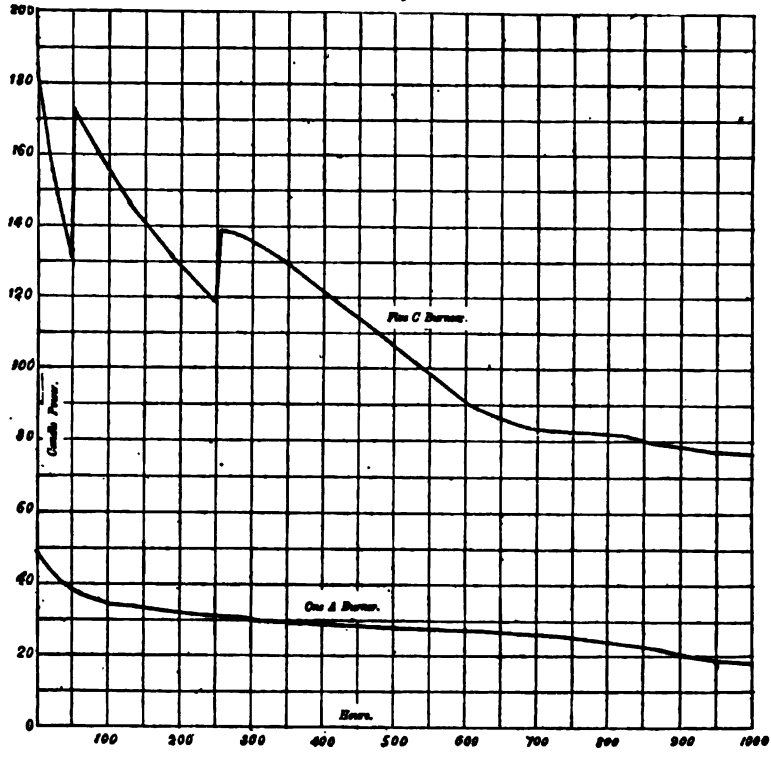
The cost, however, varies. An early installation of ten lamps in St. Vincent Street, Glasgow, was attended with very favourable results—a saving of about £11 in the first year being effected after paying off the cost of the new burners and the charge for renewal of mantles.

The New Incandescent (Sunlight Patent) Gas Lighting Company have succeeded in this country in maintaining their right to make incandescent mantles, notwithstanding the opposition of the Incandescent Gas Light Company.

Digitized by Google

In the celebrated trials—The Incandescent Gas Light Company *versus* The De Mare Incandescent Gas Light System, and The Sunlight Incandescent Gas Lamp Company—the exclusive right to manufacture mantles in the manner described by Welsbach, and irrespective of the substances of which they were composed, was claimed on behalf of the Incandescent Gas Light Company. Although Welsbach was the first to make and to describe in his specification a successful mantle, he does not appear to claim it except in conjunction with some of the rare earths (see page 296). At any rate, such was the construction placed upon the specification by Mr. Justice

FIG. 290.



Tests made in 1893 on the Incandescent Gas Light Company's Burners.

Wills, and consequently the Sunlight Company gained their case. For, although their mantle is made similarly to that of Welsbach, there is this difference that, instead of using the rare earths claimed in Welsbach's specification, they use a mixture of the common earths alumina and zirconia, or alumina alone, the mantle being afterwards sprayed with a solution of a salt of chromium.

Mantles so made give little light until sprayed with the chromium salt, when their luminosity is considerably increased. According to Professor Lewes,* these mantles give a luminosity of as much as fifteen candles per cubic foot of gas consumed.

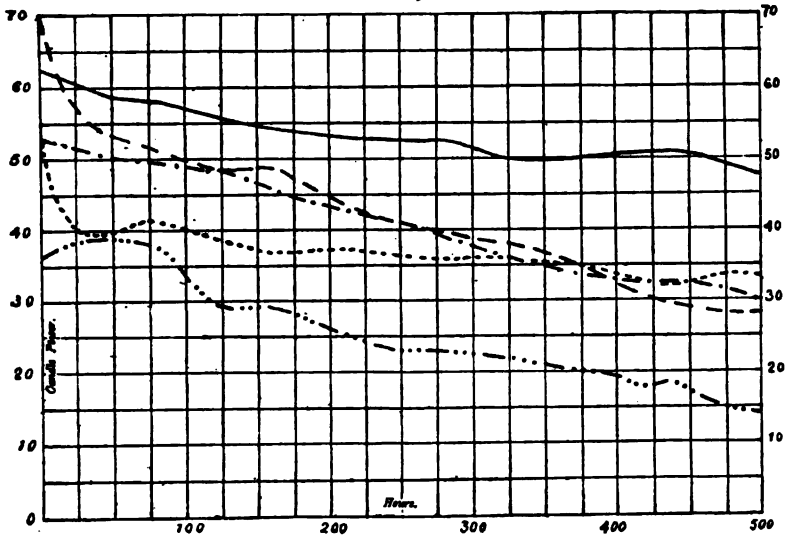
A very important question is that of the extent to which the light emitted from the mantle of an incandescent burner diminishes during

* Jour. Gas Lighting, 1876, lxvii. 1108.

Digitized by Google

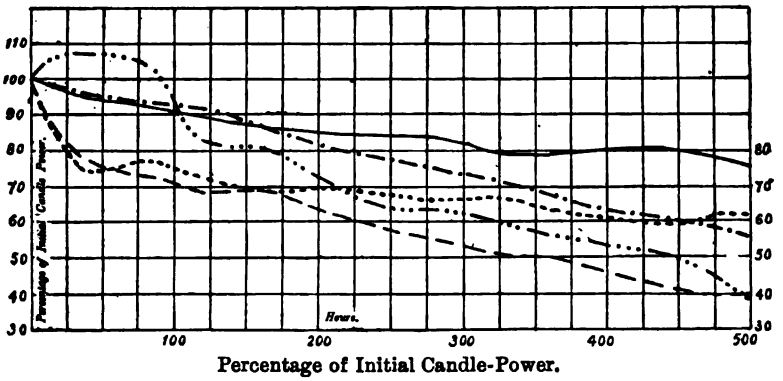
prolonged use. The "life" of a mantle is generally considered to be terminated by a serious fracture, but there is also in all cases a gradual diminution during use, which is somewhat rapid at first and afterwards

FIG. 291.



Candle-Power and Hours.

FIG. 292.



Percentage of Initial Candle-Power.

. . . — . . . Sunlight Company. —. — Incandescent Gas Light Company.
— — — — Deutsche Gasglühlicht Aktiengesellschaft. ——— Stabil.
. . . . . Neue Gasglühlicht Aktiengesellschaft.

slower. By the courtesy of the proprietors of the *Electrical Review* we are permitted to give a summary of a paper by Mr. E. A. Medley, with the illustrative diagrams which appeared in their columns.* Tests were made in 1893, in which the light given by a Welsbach "A" burner of an old form was examined, in which the mantle was supported by a side-wire, at a consumption of 3 cubic feet per hour, and also that from a group of five "C" burners, in which the mantle was supported by a central rod, at an

* *Electrical Review*, December 10, 1897, p. 824.

Digitized by Google

average consumption of 3.44 cubic feet per hour per lamp. They were burnt continuously day and night, but were turned out and relighted four times in each twenty-four hours. The curves in Fig. 290 show the results of these tests. The light from the "A" burner fell rapidly in the first 100 hours from 49 to 34 candles, or a reduction of 30.6 per cent., and from 100 to 500 hours at a slower rate to 28 candles, or a loss of 42.9 per cent. This was continued until at 1000 hours the light was that of 18 candles, or only 36.8 per cent. of the original light of 49 candles. After this the test was continued until 1450 hours, but the light remained constant at 18 candles.

The curve for the group of five "C" burners falls in 500 hours from 187 candles, or 37.4 candles each lamp, to 107, or 21.4 candles each, an average loss of 42.8 per cent., and at 1000 hours had fallen to 77, or 15.4 candles each lamp, an average total loss of 58 7 per cent. It will be seen from the curve that at 50 hours and again at 250 the light from these lamps suddenly increased without known cause, afterwards gradually decreasing again. This is a phenomenon by no means uncommon, although generally the variation is to a smaller extent.

The following tests were made on the latest types of mantles in 1897, and included two of English and three of German manufacture, and the results are shown by curves in the diagrams, Figs. 291 and 292.

Of the English mantles, those of the Sunlight Company gave less light than the others, and only two were tried. One began with a light of 45 candles, which fell in 250 hours to 20.7; the second began at 27, *rose* during 80 hours to 36.9, and then fell steadily until at 500 hours it gave a light of 13.6 candles only. The mantles made by the Incandescent Gas Light Company, of which two were tested, gave an initial light of 54.6 and 51.4 respectively, which at 500 hours had diminished to 32.4 and 27.9.

Of the mantles of German manufacture, those by the Deutsche Gasglühlicht Aktiengesellschaft, being made from the same solution, should give results similar to those of the English Incandescent Gas Light Company, and after the first 100 hours there is little difference, but the German mantles gave more light when quite new. Of these, three were tested, giving 78.3, 68.4, and 64.2 candles respectively at the commencement, and falling to 23.4. 26.1, and 35.4 in 500 hours.

The Neue Gasglühlicht mantles were inferior to the Welsbach mantles; one fell in 640 hours from 54.9 to 26.3 candles, the other two were not so good as this, and were tested for shorter times.

The Stabil mantles were superior to other kinds. Three of them when new gave 64.8, 60.3, and 62.7 candles, and after 500 hours 52.2, 43.9, and 45 candles. The last was continued until 850 hours, when it still gave 32.6 candles.

In Figs. 290 and 291 the curves show the candle power of light given after progressive times in hours, and in Fig. 292 the curves show the progressive diminution of light for each kind of mantle shown in Figs. 290 and 291 expressed in percentages of the initial light.

The following table, compiled from the average curves in Figs. 291 and 292, gives the main features of the tests:—

Digitized by Google

Make of Mantle.	Candle Powers.			Percentage Fall in	
	New.	100 hours.	500 hours.	100 hours.	500 hours.
Sunlight Company . . .	36	23.4	14	7	61.2
Incandescent Gas Light Company.	52.9	49	29.7	7	43.8
Deutsche Gasglühlicht Aktiengesellschaft . . .	70.3	49.7	28.2	29	59.9
Neue Gasglühlicht Aktiengesellschaft.	53.5	40.3	33.3	25	37.7
Stabil	62.6	57.1	47.5	9	24.1

For a full historical account of gas burners up to the year 1884, readers are referred to the treatise by Owen Merriman, published by W. King, Fleet Street, London, to which the author wishes to acknowledge his indebtedness.

Digitized by Google

Digitized by Google

INDEX.

A

Acetylene, 244
  enrichment value of, 247
Ammonia, estimation of, in ammoniacal liquor, 98
  estimation of, in gas, 94, 145
  solution, manufacture of, from gas liquor, 101
  sulphate of, annual production of, 107
    cost of manufacture, 106
    Feldmann's apparatus, 102
    Grüneberg and Simon's apparatus, 101
    manufacture of, from gas liquor, 99, 107
    sale price of, 107
Ammoniacal liquor, 97
  estimation of ammonia in, 98
  valuation of, 98
Argand burners, 258
  illuminating power of, 259, 260
  London Argand, 261
Arrol-Foulis charging machine, 49
Audouin and Bérard's experiments on gas burners, 261

B

Bandsept incandescent burner, 302
Bat's-wing burner. *See* Flat-flame burners
Battery condenser, 68
Beale's exhauster, 79
Bench. *See* Furnaces for carbonisation
Benzene, vapour tension of, 205
Borradaile's governor burner, 272
Bowditch regenerative burner, 284
Braddock's equilibrium station governor, 170
Bray's "regulator," and special burners, 264
  high power burners, 267
  street lantern, 270
Brönner's burners, 264
Bunte's gas-analysis apparatus, 46
Burners. *See* Argand burners, flat-flame burners, governor burners, incandescent burners, regenerative burners, sun burners

C

Calcium carbide, manufacture of, 246
Calorific value of coal-gas, 242
  values of different gases, 255, 256
Calorimeter, Hartley's, 250
  Junker's, 251
Cannel coal, analysis of, 9, 14–16
Carbide of calcium, manufacture of, 246
Carbon bisulphide, estimation of, in gas, 142
  removal of, from gas, 122
Carbonic acid, estimation of, in gas, 96, 141, 142
  removal of, from gas, 121, 128, 129
Carbonisation, continuous, 57
Carburetted water gas, 226
Chandler and Stevenson's self-acting dip-pipe, 63
Chimney, Argand, 279
  Kerr and Green's, 278
Clamond incandescent burners, 295, 296
Clark's regenerative burner, 287
Claus purifying process, 129
Clay retorts. *See* Retorts
Clegg's gas-meter (dry), 195
  gas-meter (wet), 187
  hydraulic gas-meter (wet), 190
Cleland's exhauster, 83
  scrubber, 93
Coal, cannel, composition of, 9, 14–16
  carbonisation of, 18
    products formed in, 18
  composition of, 17
  effect of temperature on carbonisation of, 20–22
Coal, gas-, analysis of, 9–16
Coal, nitrogenous products from, 22
  sulphur in, 23
Coal-tar, enriching gas with, 212
Cockspur burner, 258
Comparison of lamps for street lighting, 267
Condensers, 66
  action of, 70
  atmospheric, 66
  battery, 68
  Graham's flat screw, 66
  influence of, on the illuminating power of gas, 70, 73
  Kirkham's, 68
  Morris and Cutler's perfect, 70
  Wright's, 68
Cowan's automatic pressure changer, 174
Coze's drawing and charging machine, 60
  inclined retorts, 60
"Cracking" hydrocarbons, 207
Croll and Richard's gas-meter (dry), 196
Croll's furnace, 31
  washer, 84
Cromartie lamp, 280, 289
  lamp and ventilating shaft, 280
Crossley's indicator, 175
  meters, 188, 189
Cutler's guide framing, 161
  hydraulic valve, 113
Cyanogen in gas residuals, 107

D

Defries' gas-meter (dry), 196
Denayrouze incandescent burner, 301

Digitized by Google

Dillaman's tar-receiver, 83
Dinsmore enriching process, 212
Dip-pipe, 60
  Chandler and Stevenson's, 63
Distributing mains, 177
District governors. *See* Governors, district
Dry-lime purifier, 111, 125

E

EDGERTON water-gas apparatus, 227
Elliott's continuous carbonisation, 57
Enrichment processes, 201, 208
  value of acetylene, 247
  with coal-tar, 212
Esson's gas-meter (wet), 190
Exhausters, 79
Extractors. *See* Tar extractors

F

FELDMANN's sulphate of ammonia apparatus, 102
Ferrocyanide, manufacture of, from gas residuals, 107
Fish-tail burner. *See* Flat-flame burners
FLAT-FLAME BURNERS, 262. *See also* Governor burners
  bat's-wing, 262
    Bray's special, 265
    Brönner's, 264
    hollow top, 263
    illuminating power of, 266
    Sugg's, 263
  Bray's fish-tail, 264
    high-power, 266
    slit-union, 265
  fish-tail, 262
    illuminating power of, 265
  Siemens' regenerative, 286
  Sugg's table-top, 267
Folkard's process for estimating carbonic acid in gas, 142
Foulis district governor, 182
  hydraulic drawing machine, 49
FURNACES FOR CARBONISATION, 29
  Croll's, 31
  Hunt's, 41
  Klönne's, 41
  Liegel's, 38
  Lowe's, 34
  Schilling's regenerative, 35
  Siemens' recuperative, 43
  Valon's, 45

G

GADD and Mason's spiral guides, 162
Gardner's gas globe, 276
GAS,
  calorific value of, 242
    method of determining, 249
  early history of, 3
  estimation of ammonia in, 94
    of carbonic acid in, 96
    of sulphuretted hydrogen in, 97
  hydrocarbons for enriching, 202
  illuminating power of, 210 *et seq.*
    effect of enriching material on, 211
  manufacture of, 7
  measurement of, 148
Gas analysis, 137 *et seq.*
Gas-analysis apparatus, Bunte's, 46
  Orsat-Muencke, 138
Gas burners, 257 *et seq.* *See* Argand burners, flat-flame burners, governor burners, incandescent burners, regenerative burners
Gas-coal, analysis of, 9–16
Gas globes. *See* Globes
Gas-holder tanks, 151
Gas holders, 150–167
  trussed, 156
GAS METERS,
  (dry), Clegg's, 195
  (dry), Croll and Richards', 196
  (dry), Defries', 196
  prepayment, 198
  (wet), 187
  (wet), Clegg's, 187
  Clegg's hydraulic, 190
  Crossley open float, 188
  Esson's, 190
  Hunt's compensating, 193
  Mead's, 193
  Pinchbeck's, 194
  Sanders and Donovan's compensating, 19
  Warner and Cowan's, 190
Gas, oil-. *See* Oil-gas
Gas, purified, analysis of, 144
    estimation of ammonia in, 145
      of sulphur in, 146
      of sulphur compounds in, 14
      of sulphuretted hydrogen in, 145
Gas, purification of, by oxide of iron, 135. *See also* Purification
  removal of carbonic acid from, 128
    of sulphuretted hydrogen from, 120, 135
    of sulphuretted hydrogen and carbonic acid from, 121, 128, 129
  retorts, 24
  storage of, 148
  unpurified, analysis of, 137
    estimation of carbon bisulphide in, 142
    of carbonic acid in, 141
    of sulphuretted hydrogen in, 140, 141
  water-. *See* Water-gas
Gases, calorific value of, 255, 256
Gadd and Mason's spiral guides, 162
Gardner's globe, 276
Giroud's rheometer, 272
Globe, Gardner's, 276
  Kerr and Green's, 278
  Sugg's Christiania, 276
GOVERNOR BURNER,
  Borradaile's, 272
  Giroud's rheometer, 272
  Orme's, 274
  Parkinson's automatic, 274
  Peeble's modified, 274
  Peeble's (needle), 274
  Sugg's Christiania burner, 272. 276
Governors. *See also* Governor burner
  differential, Jones', 183
  district, 182
    Foule's, 182
    Parkinson's, 183
    Peeble's, 182
  Sugg's steatite float, 272
  station, 168
    Braddock's, 170
    Hunt's equilibrium, 170
    Parkinson's double-cone equilibrium, 170
Grafton's exhauster, 81
Graham's horizontal condenser, 66
Granger-Collins water-gas apparatus, 232
Granger's modification of Lowe's water-gas apparatus, 232
Grimston's burner, 287

Digitized by Google

Grüneberg and Simon's sulphate of ammonia apparatus, 101
Guide framing, Cutler's, 161
for gas holders, 159
Guides, Pease's wire-rope, 164
spiral, Gadd and Mason's, 162

H

HARCOURT'S colour test for carbon bisulphide, 142
Hartley's calorimeter, 250
Holgate's ammoniacal liquor purifier, 132
Hunt's compensating gas meter (wet), 193
equilibrium station governor, 170
modification of Klönne's furnace, 41
sunlight, 293
washer, 90
Hydraulic main, 60
valve for dry-lime purifiers, 113
Hydrocarbons for enriching coal gas, 202
Hydrocyanic acid, estimation of, in coal gas, 108

I

ILLUMINATING POWER, effect of dry-air supply on, 281
of Argand burners, 259, 260
of batswing burners, 266
of fish-tail burners, 265
of gas, 210 *et seq.*
of gas, effect of enriching material on, 211
of incandescent burners, 302
of naphthalene, 185
of slit-union burners, 266
INCANDESCENT BURNERS, Bandsept, 302
Clamond, 295
Denayrouze, 301
improved Clamond, 296
Kern, 302
Lewis, 294
"Sunlight," 304
Welsbach, 296 *et seq.*
Indicator, Crossley's, 175
Wright's, 176

J

JONES' differential governor, 183
Junker's calorimeter, 251

K

KIRKHAM'S scrubber-washer, 94
Kern incandescent burner, 302
Kerr and Green's chimney, 278
globe, 278
King's turned and bored joint for mains, 179
Klönne's furnace, 41
Körting's steam-jet exhauster, 83

L

LANTERN, Bray's street, 270
Sugg's street, 270
Leslie's argand regenerative burner, 283
Lewis' incandescent burner, 294
Liegel's regenerative furnace, 38
Lime, analysis of, 136
purifiers, 110, 111, 125
Livesey's multiple lift gas-holders, 162
scrubber, 90
washer, 75
Lowe's furnace, 34
water-gas apparatus, 228, 232, 236

M

MAIN, hydraulic, 60
Mains, distributing, 177
joint for, 178
King's joint for, 179
siphon for, 179
velocity of gas in, 179
Mansfield oil-gas producer, 221
Mantle for Welsbach burner, 296, 300, 306
Maxim and Clark's apparatus for enrichment, 208
Mead's gas-metre (wet), 193
Measurement of gas, 148
Merrifield-Westcott-Pearson's water-gas apparatus, 233
Meter. *See* Gas meters
Meter governor, 275
Morris and Cutler's perfect condenser, 70

N

NAPHTHALENE, illuminating power of, 185
in service pipes, 184, 187
in tar, 185

O

OIL-GAS, 219
Mansfield producer, 221
Patterson's producer, 221
Pintsch's, 220
Young and Bell's producer, 223
Orme's governor burner, 274
regulator, 274
suspension regulator, 274
Oven. *See* Furnaces for carbonisation
Oxygen, use of, for purifying gas, 126

P

PADDON'S scrubber-washer, 93
Paraffins for enriching gas, 201
Parkinson's automatic governor burner, 274
district governor, 183
double-cone equilibrium station governor, 170
pressure raiser, 198
street-lamp regulator, 274
Patterson's oil-gas producer, 221
Pease's wire-rope guides, 164
Peeble's district governor, 183
modified governor burner, 274
needle governor burner, 274
Pelouze and Audouin's tar extractor, 75
Penny-in-the-slot meters, 198
Pinchbeck's gas meter (wet), 194
Pintsch's oil-gas, 220
Prepayment meters (dry), 198
Pressure changer, Cowan's automatic, 174
Price's automatic, 175
raiser, Parkinson's, 198
Price's automatic pressure changer, 175
Purification of gas, 120–137
of gas, complete, 122
of gas, from bisulphide of carbon, 122
of gas, partial, 120
Purifier house, plan of, 118
Purifiers, 110–120
proportionate size of, 120
Purifying materials for gas, 135–137

Digitized by Google

R

REGENERATIVE BURNER, Bowditch's, 284
Clarke's, 287
Grimston's, 287
Leslie's argand, 283
Schulke's, 290
Siemens', 286
flat-flame, 286
Sugg's Cromartie, 289
Wenham, 289
Regulator, Orme's, 274
Orme's suspension, 274
Parkinson's street lamp, 274
Retort-house, 64
Retort-lids, 25
Holman's fastening, 25
Retorts, 24
inclined, 60
setting of, 29
Rheometer, Giroud's, 272
Ross drawing and charging machine, 52

S

SANDERS and Donovan's compensating gas meter (wet), 190
Sanders' water-gas apparatus, 227
Schilling's regenerative furnace, 35
Schulke's regenerative burner, 290
street lamp, 290
Scrubbers, 85
Service pipes, 183
stoppage of, by naphthalene, 184, 187
Sheard's apparatus for estimating carbonic acid in gas, 141
Siemens' flat-flame regenerative burner, 286
recuperative furnace, 43
regenerative burner, 284
Slit-union burner, illuminating power of, 266
Spent lime, examination of, 136
Spent oxide of iron, estimation of sulphur in, 135
Springer's water-gas apparatus, 232
Station governor. *See* Governor, station
Stoking machinery, 48
Storage of gas, 148
Street lamps, comparison of, 267
Strode's sunlight, 293
Sugg's Christiania globe, 276
Christiania governor burner, 272, 276
Cromartie regenerative burner, 287
"London argand," 261
street lantern, 270
table-top burner, 267
Sulphur compounds, estimation of in gas, 146
Sulphur, estimation of in gas, 146
Sulphuretted hydrogen, estimation of, in gas, 97, 140, 141
removal of, from gas, 120, 135, 145
Sun-burner, Hunt's, 293
Strode's, 293
Sun-burners, 291
"Sunlight Co." incandescent burner, 304

T

TANKS for gas-holders, 151
Tar-extractors, 75
Tar, naphthalene in, 185
Tension of benzene vapour, 205
of water vapour, 205
Tessie du Motay water-gas apparatus, 229
Trussed gas-holder, 156

V

VALON's regenerative furnace, 45
Valves for lime purifiers, 111–117
Vapour tension of benzene, water, &c., 204

W

WADSWORTH's hollow-top burner, 263
Walker's exhauster, 81
purifying machine, 94
washer and scrubber, 87
Waller's exhauster, 81
Warner's scrubber, 90
Warner and Cowan's gas meter (wet), 190
Washers and scrubbers, 97
WATER-GAS APPARATUS,
Egerton, 227
Granger-Collins, 232
Granger's modification of Lowe's, 232
Lowe's, 228, 232, 236
Merrifield-Westcott-Pearson, 236
Sanders', 227
Springer's, 232
Tessie du Motay, 229
Wilkinson's, 229
Water-gas, calorific value of, 242
carburetted, 226
composition of, 240
Water, vapour tension of, 205
Weck centre valve, 114
Welsbach incandescent burners, 296 *et seq.*
Wenham's regenerative burner, 289
West's drawing and charging machine, 52
Wet-lime purifier, 110
Wilkinson's water-gas apparatus, 229
Wilton's patent automatic discharger (sulphate of ammonia), 103
Wright's condenser, 68
indicator, 176

Y

YOUNG and Bell's oil-gas producer, 223

Digitized by Google

Catalogue of the Medical, Dental, Pharmaceutical, Chemical, and Scientific Books Published by P. Blakiston's Son & Co., 1012 Walnut Street, Philadelphia.

Established 1843.

SPECIAL NOTE.

The prices as given in this catalogue are absolutely net—no discount will be allowed retail purchasers under any consideration. This rule has been established in order that every one will be treated alike, a general reduction in former prices having been made to meet previous retail discounts. Upon receipt of the advertised price any book will be forwarded by mail or express, **all charges prepaid.**

We keep a large stock of Miscellaneous Books relating to Medicine and Allied Sciences, published in this country and abroad. Inquiries in regard to prices, date of edition, etc., will receive prompt attention.

CATALOGUES AND CIRCULARS SENT FREE UPON APPLICATION:

Catalogue No. 1.—A complete list of the titles of all our publications on Medicine, Dentistry, Pharmacy, and Allied Sciences, with Classified Index.

Catalogue No. 3.—Pharmaceutical Books.

Catalogue No. 4.—Books on Chemistry and Chemical Technology.

Catalogue No. 5.—Books for Nurses and Lay Readers.

Catalogue No. 6.—Books on Dentistry and Books used by Dental Students.

Catalogue No. 7.—Books on Hygiene and Sanitary Science; Including Water and Milk Analysis, Microscopy, Physical Education, Hospitals, etc.

Catalogue No. 8.—List of about 300 Standard Books classified by Subjects.

Special Circulars.—Morris' Anatomy; Gould and Pyle's Cyclopedia; Deaver's Surgical Anatomy; Tyson's Practice; Gould's Medical Dictionaries; Books on the Eye; The ? Quiz-Compends ? Series, Visiting Lists, etc. We can also furnish **sample pages** of most of our publications.

P. Blakiston's Son & Co.'s publications may be had through the booksellers in all the principal cities of the United States and Canada, or any book will be sent, postpaid, upon receipt of the price. Special terms of payment will be allowed to those of approved credit. No discount can be allowed retail purchasers under any circumstances. Money should be remitted by express or post-office money order, registered letter, or bank draft.

SEE PAGE 4, GOULD'S MEDICAL DICTIONARIES.

NO. 1—6-1-1900.

Digitized by Google

THE PRICES OF ALL BOOKS ARE NET.

CLASSIFIED LIST, WITH PRICES,

OF ALL BOOKS PUBLISHED BY

P. BLAKISTON'S SON & CO., PHILADELPHIA.

When the price is not given below, the book is out of print or about to be published. Cloth binding, unless otherwise specified. For full descriptions see following Catalogue.

ANATOMY.

Ballou. Veterinary Anat. $0.80
Broomell. Anatomy and Histol. of Mouth and Teeth. 4.50
Eckley. Practical Anatomy. 3.50
Gordinier. Anatomy of Nervous System. Illustrated. 6.00
Heath. Practical. 7th Ed. 4.25
Holden. Dissector. 2 Vols. ——
—— Osteology. 8th Ed. 5.25
—— Landmarks. 4th Ed. 1.00
Macalister's Text-Book. - 5.00
Marshall's Phys. & Anatomical Diagrams. $40.00 and 60.00
Morris. Text-Book Anat. New Ed. 790 Ill. Clo., $6.00; Sh., 7.00
Potter. Compend of. 6th Ed. 133 Illustrations. - .80
Wilson's Anatomy. 11th Ed. 5.00
Windle. Surface Anatomy. 1.00

ANESTHETICS.

Buxton. Anæsthetics. - 1.50
Turnbull. 4th Ed. - 2.50

BRAIN AND INSANITY.

Blackburn. Autopsies. - 1.25
Gowers. Diagnosis of Diseases of the Brain. 2d Ed. 1.50
Horsley. Brain and Sp. Cord. 2.50
Ireland. Mental Affections of Children. - - - 4.00
Lewis. Mental Diseases. 7.00
Mann's Psychological Med. 3.00
Régis. Mental Medicine. - 2.00
Shuttleworth. Mentally Deficient Children. - - - 1.50
Stearns. Mental Dis. Illus. 2.75
Tuke. Dictionary of Psychological Medicine. 2 Vols. 10.00
Wood. Brain and Overwork. .40

CHEMISTRY.

Technological Books, Water, Milk, etc.

Allen. Commercial Organic Analysis. Vol. I. - - 4.50
—— Vol. II. Part I. - 3.50
—— Vol. II. Part II. - 3.50
—— Vol. II. Part III. - ——
—— Vol. III. Part I. - ——
—— Vol. III. Part II. - 4.50
—— Vol. III. Part III. - 4.50
—— Vol. IV. - - - 4.50
Bartley. Medical and Pharmaceutical. 5th Ed. - 3.00
—— Clinical Chemistry. 1.00
Bloxam's Text-Book. 8th Ed. 4.25
Caldwell. Qualitative and Quantitative Analysis. - 1.50
Cameron. Oils & Varnishes. 2.25
—— Soap and Candles. - 2.00
Clowes and Coleman. Quantitative Analysis. - - ——
Gardner. Brewing, etc. - 1.50
—— Bleaching and Dyeing. 1.50
Groves and Thorp. Chemical Technology. Vol. I. Fuels 5.00
—— Vol. II. Lighting. - 4.00
—— Vol. III. Lighting - ——
—— Vol. IV. Elec. Lighting. ——
Holland. Urine, Gastric Contents, Poisons and Milk Analysis. 6th Ed. - - - 1.00
Leffmann's Compend. - .80
—— Milk Analysis. - - 1.25
—— Water Analysis. - - 1.25
—— Structural Formulæ. - 1.00
Muter. Pract. and Anal. 1.25
Oettel. Electro-Chem. - .75
—— Electro-Chem. Exper. .75
Richter's Inorganic. 4th Ed. 1.75
—— Organic. 3d Ed. 2 Vols.
Vol. I. Aliphatic Series. 3.00
Vol. II. Carbocyclic " 3.00
Smith. Electro-Chem. Anal. 1.25
Smith and Keller. Experiments. 3d Ed. Illus. $0.60
Sutton. Volumetric Anal. ——
Symonds. Manual of. 2.00
Traube. Physico-Chem. Meth. 1.50
Thresh. Water Supplies. - 2.00
Ulzer and Fraenkel. Technical Chemical Analysis. 1.25
Woody. Essentials of. 4th Ed. 1.50

CHILDREN.

Cautley. Feeding of Infants. 2.00
Hale. Care of. - .50
Hatfield. Compend of. .80
Meigs. Milk Analysis. - .50
Power. Surgical Diseases of. 2.50
Smith. Wasting Diseases of. 2.00
Starr. Digestive Organs of. 2.00
—— Hygiene of the Nursery. 1.00
Taylor and Wells. Manual. 4.00

CLINICAL CHARTS.

Griffiths. Temp't're Charts. Pads of 50 - - - .50
Keen. Outline Drawings of Human Body. - - 1.00
Schreiner. Diet Lists. Pads, .75

COMPENDS

And The Quiz-Compends.

Ballou. Veterinary Anat. .80
Brubaker's Physiol. 9th Ed. .80
Gould and Pyle. The Eye. .80
Hall. Pathology. Illus. ——
Hatfield. Children. - .80
Horwitz. Surgery. 5th Ed. .80
Hughes. Practice. 2 Pts. Ea. .80
Landis. Obstetrics. 6th Ed. .80
Leffmann's Chemistry. 4th Ed. .80
Mason. Electricity. - .75
Potter's Anatomy, 6th Ed. .80
—— Materia Medica. 6th Ed. .80
Schamberg. Skin Diseases. .80
Stewart, Pharmacy. 5th Ed. .80
Warren. Dentistry. 3d Ed. .80
Wells. Gynecology. 2d Ed. .80

CONSUMPTION.

Harris and Beale. Pulmonary Consumption. - - 2.50
Knopf. Pulmon. Tuberculosis. 3.00
Powell. Diseases of Lungs. 4.00

DENTISTRY.

Barrett. Dental Surg. - 1.00
Broomell. Anat. and Hist. of Mouth and Teeth. - - 4.50
Fillebrown. Op. Dent. Illus. 2.25
Gorgas. Dental Medicine. 4.00
Harris. Principles and Prac. 6.00
—— Dictionary of. 6th Ed. 5.00
Heath. Dis. of Jaws. - 4.50
—— Lectures on Jaws. Bds. .50
Richardson. Mech. Dent. 5.00
Smith. Dental Metallurgy. 1.75
Taft. Index of Dental Lit. 2.00
Talbot. Irregularity of Teeth. 3.00
Tomes. Dental Surgery. 4.00
—— Dental Anatomy. 4.00
Warren's Compend of. - .80
—— Dental Prosthesis and Metallurgy. Illus. - 1.25
White. Mouth and Teeth. .40

DIAGNOSIS.

Brown. Medical. 4th Ed. 2.25
Fenwick. Medical. 8th Ed. 2.50
Tyson's Manual. 3d Ed. Illus. 1.50

DICTIONARIES.

Gould's Illustrated Dictionary of Medicine, Biology, and Allied Sciences, etc. 5th Edition. Leather, $10.00; Half Russia, Thumb Index, - 12.00
Gould's Student's Medical Dictionary. 10th Ed., ½ Lea., $3.25; ½ Mor., Thumb Ind. $4.00
Gould's Pocket Dictionary—30,000 medical words. 4th Edition. Enlarged. Leather, 1.00
Gould and Pyle. Cyclopedia of Med. and Surg. One Vol. Illus. Leather, 10.00
Harris' Dental. Clo. 5.00; Shp. 6.00
Longley's Pronouncing. - .75
Maxwell. Terminologia Medica Polyglotta. - - 3.00
Treves. German-English. 3.25

EAR.

Burnett. Hearing, etc. .40
Dalby. Diseases of. 4th Ed. 2.50
Hovell. Treatise on. - ——
Pritchard. Diseases of. 3d Ed. 1.50
Woakes. Deafness, Giddiness, and Noises in the Head. 2.00

ELECTRICITY.

Bigelow. Plain Talks on Medical Electricity. 43 Illus. 1.00
Hedley. Therapeutic Elec. 2.50
Jacobi. Electrotherapy - ——
Jones. Medical Electricity. 3d Ed. Illus. - ——
Mason's Electricity and its Medical and Surgical Uses. .75

EYE.

Donders. Refraction. - 1.25
Fick. Diseases of the Eye. 4.50
Gould and Pyle. Compend. .80
Gower's Ophthalmoscopy. 4.00
Harlan. Eyesight. - .40
Hartridge. Refraction. 10th Ed. 1.50
—— Ophthalmoscope. 3d Ed. 1.50
Hansell and Reber. Muscular Anamolies of the Eye. 1.50
Hansell and Bell. Clinical Ophthalmology. 120 Illus. 1.50
Jessop's Manual of Diseases of Eye. - - - - 3.00
Morton. Refraction. 6th Ed. 1.00
Ohlemann. Ocular Therap. 1.75
Phillips. Spectacles and Eyeglasses. 49 Illus. 2d Ed. 1.00
Swanzy's Handbook. 6th Ed. 3.00
Thorington. Retinoscopy. 1.00
—— Refraction. 210 Illus. 1.50
Walker. Student's Aid. 1.50

FEVERS.

Collie, On Fevers. - 2.00
Goodall and Washbourn. 3.00

GYNECOLOGY.

Byford (H. T.). Manual. 2d Edition. 341 Illustrations. 3.00
Dührssen. Gynecological Practice. 105 Illustrations. 1.50
Montgomery. Text-book of. 500 Illus. - - - ——
Lewers. Dis. of Women. 2.50
Wells. Compend. Illus. .80

HEALTH AND DOMESTIC MEDICINE.

Bulkley. The Skin. - .40
Burnett. Hearing. - .40
Cohen. Throat and Voice. .40
Dulles. Emergencies. 5th Ed. 1.00
Harlan. Eyesight. - .40
Hartshorne. Our Homes. .40
Osgood. Dangers of Winter. .40
Packard. Sea Air, etc. .40
Richardson's Long Life. .40
Westland. The Wife and Mother. - - - - 1.50
White. Mouth and Teeth. .40
Wilson. Summer and its Dis. .40
Wood. Brain and Overwork. .40

Digitized by Google

HISTOLOGY.

Stirling. Histology. 2d Ed. $2.00
Stöhr's Histology. Illus. - 3.00

HYGIENE.

Canfield. Hygiene of the Sick-Room. - - - - 1.25
Coplin. Practical Hygiene. ——
Ernst. Prophylaxis. - - ——
Kenwood. Public Health Laboratory Guide. - 2.00
Lincoln. School Hygiene. .40
McNeill. Epidemics and Isolation Hospitals. - - 3.50
Notter and Firth. - ——
Parkes' (L. C.), Manual. 2.50
——— Elements of Health. 1.25
Starr. Hygiene of the Nursery. 1.00
Stevenson and Murphy. A Treatise on Hygiene. In 3 Vols. *Circular upon application.* Vol. I, 6.00 Vol. II, 6.00 Vol. III, 5.00
Thresh. Water Supplies. 2.00
Wilson's Handbook. 8th Ed. 3.00
Weyl. Coal-Tar Colors. 1.25

MASSAGE, Etc.

Kleen and Hartwell. - 2.25
Mitchell and Gulick. Mechanotherapy. - - - ——
Ostrom. Massage. 105 Illus. 1.00
Ward. Notes on. Paper Cov. 1.00

MATERIA MEDICA.

Biddle. 13th Ed. Cloth, 4.00
Bracken. Materia Med. 2.75
Coblentz. Newer Remedies. 1.00
Davis. Essentials of. - 1.50
Gorgas Dental. 5th Ed. 4.00
Groff. Mat. Med. for Nurses. 1.25
Heller. Essentials of. - 1.50
Potter's Compend of. 6th Ed. .80
Potter's Handbook of. 7th Ed. Cloth, $5.00; Sheep, 6.00
Sayre. Organic Materia Med. and Pharmacognosy. - 4.50
White and Wilcox. Mat. Med., Pharmacy, Pharmacology, and Therapeutics. 4th Ed. Enlarged. Cl., $3.00; Sh. 3.50

MEDICAL JURISPRUDENCE.

Mann. Forensic Med. - 6.50
Reese. Med. Jurisprudence and Toxicology, 5th Ed. $3.00; Sh. 3.50

MICROSCOPE.

Carpenter. The Microscope. 8th Ed. 800 Illus. - ——
Lee. Vade Mecum of. - ——
Reeves. Med. Microscopy. 2.50
Wethered. Medical Microscopy. Illus. - - - 2.00

MISCELLANEOUS.

Black. Micro-organisms. .75
Bramwell. Anæmia. - 2.50
Burnet. Food and Dietaries. 1.50
Cohen. Organotherapy. ——
Da Costa. Clinical Pathology of the Blood. - - - ——
Davis. Alimentotherapy. ——
Duckworth. On Gout. - 6.00
Fenwick. Ulcer of Stomach. 3.50
Garrod. Rheumatism, etc. 5.00
Gould. Borderland Studies. 2.00
Gowers. Dynamics of Life. .75
Greene. Medical Examination in Life Insurance. - - ——
Haig. Uric Acid. - - ——
——— Diet and Food. - - 1.00
Hare. Mediastinal Disease. 2.00
Hemmeter. Diseases of Stomach. 2d Edition. Illus. - 6.00
Henry. Anæmia. - - .50
Leffmann. Coal Tar Products. 1.25
Marshall. Women's Med. Col. 1.50
McCook. Amer. Spiders. 50.00
New Sydenham Society's Publications, each year. - 8.00
Parrish. Inebriety. - 1.00
St. Clair. Medical Latin. 1.00
Sansom. Dis. of Heart. - 6.00
Tessier. Pneumotherapy. ——
Thorne. Schott Methods in Heart Disease. - - 1.75
Treves. Physical Education. .75
Weber and Hinsdale. Climate. - - - - - - ——
Winternitz. Hydrotherapy. ——

NERVOUS DISEASES, Etc.

Beevor. Nervous Diseases. $2.50
Dercum. Rest, Hypnotism, Mental Therapeutics. - ——
Gordinier. Anatomy of Central Nervous System. - 6.00
Gowers. Manual of. 530 Illus. Vol. 1, $4.00; Vol. 2, - 4.00
——— Syphilis and the Nervous System. - - - 1.00
——— Diseases of Brain. 1.50
——— Clinical Lectures. 2.00
——— Epilepsy. New Ed. ——
Horsley. Brain and Spinal Cord. Illus. - - - 2.50
Ormerod. Manual of. - 1.00
Osler. Chorea. - - 2.00
Preston. Hysteria. Illus. 2.00

NURSING.

Brown. Physiology for Nurses. .75
Canfield. Hygiene of the Sick-Room. - - - - - 1.25
Cuff. Lectures on. 2d Ed. 1.25
Domville's Manual. 8th Ed. .75
Ernst. Prophylaxis. - - ——
Fullerton. Obst. Nursing. 1.00
——— Surgical Nursing. 1.00
Gould. Pocket Medical Dictionary. Limp Morocco. 1.00
Groff. Mat. Med. for Nurses. 1.25
Humphrey. Manual. 17th Ed. 1.00
Horwitz. Duties of the Surgical Nurse. - - - - ——
Starr. Hygiene of the Nursery. 1.00
Temperature Charts. Pads. .50
Voswinkel. Surg. Nursing. 1.00

OBSTETRICS.

Caseaux and Tarnier. Text-Book of. Colored Plates. 4.50
Davis. Obstetrics. 3d Ed. ——
Landis. Compend. 6th Ed. .80
Winckel's Text-book. 5.00

PATHOLOGY.

Barlow. General Pathology. 5.00
Blackburn. Autopsies. 1.25
Coplin. Manual of. 3d Ed. 3.50
Da Costa. The Blood. - ——
Gilliam. Essentials of. - .75
Hall. Compend. Illus. 2d Ed. ——
Hewlett. Bacteriology. - 3.00
Virchow. Post-mortems. .75
Whitacre. Lab. Text-book. 1.50
Williams. Bacteriology. 1.50

PHARMACY.

Beasley's Receipt-Book. - 2.00
——— Formulary. - - 2.00
Coblentz. Manual of Pharm. 3.50
Proctor. Practical Pharm. 3.00
Robinson. Latin Grammar of. 1.75
Sayre. Organic Materia Med. and Pharmacognosy. 2d Ed. 4.50
Scoville. Compounding. 2.50
Stewart's Compend. 5th Ed. .80
U. S. Pharmacopœia. 7th Revision. Cl. $2.50; Sh., 3.00
Select Tables from U. S. P. .25
Tuson. Veter. Pharmacopœia. 2.25

PHYSIOLOGY.

Birch. Practical Physiology. 1.75
Brown. Physiol. for Nurses. .75
Brubaker's Compend. Illustrated. 9th Ed. - - .80
Kirke's New 15th Ed. (Halliburton.) Cloth, $3.00; Sh., 3.75
Landois' Text-book. 845 Illustrations. - - - - ——
Starling. Elements of. - 1.00
Stirling. Practical Phys. 2.00
Tyson's Cell Doctrine. - 1.50

POISONS.

Reese. Toxicology. 4th Ed. 3.00
Tanner. Memoranda of. .75

PRACTICE.

Beale. Slight Ailments. 1.25
Fowler's Dictionary of. - 3.00
Hughes. Compend. 2 Pts. ea. .80
——— Physician's Edition. 1 Vol. Morocco, Gilt edge. 2.25
Taylor's Manual of. - 4.00
Tyson. The Practice of Medicine. Illus. Cl. $5.50; Sheep, 6.50

PRESCRIPTION BOOKS.

Beasley's 3000 Prescriptions. $2.00
——— Receipt Book. - 2.00
Davis. Materia Medica and Prescription Writing. - 1.50

SKIN.

Bulkley. The Skin. - .40
Crocker. Dis. of Skin. Illus. ——
Impey. Leprosy. - - 3.50
Schamberg. Compend. .80
Van Harlingen. Diagnosis and Treatment of Skin Dis. 3d Ed. 60 Illus. - - 2.75

SURGERY AND SURGICAL DISEASES.

Cripps. Ovariotomy and Abdominal Surgery. - - 8.00
Butlin. Surgery of Malignant Disease. - - - 4.50
Deaver. Appendicitis. - 3.50
——— Surgical Anatomy. - 21.00
Dulles. Emergencies. - 1.00
Hamilton. Tumors. 3d Ed. 1.25
Heath's Minor. 11th Ed. 1.25
——— Diseases of Jaws. - 4.50
——— Lectures on Jaws. .50
Horwitz. Compend. 5th Ed. .80
Jacobson. Operations of. - 3.00
Lane. Surgery of Head. 5.00
Macready on Ruptures - 6.00
Maylard. Surgery of the Alimentary Canal. - - 3.00
Morris. Renal Surgery. 2.00
Moullin. Complete Text-book. 3d Ed. by Hamilton, 600 Illustrations. - - 6.00
Roberts' Fractures. - 1.00
Smith. Abdominal Surg. 10.00
Swain. Surgical Emer. - 1.75
Voswinkel. Surg. Nursing. 1.00
Walsham. Practical Surg. 3.00

THERAPEUTICS.

Biddle. Materia Medica and Therapeutics. 13th Edition. 4 00
Coblentz. New Remedies. 1.00
Cohen. Physiologic Therapeutics. - - - - - ——
Mays. Theine. - - .50
Potter's Compend. 6th Ed. .80
——— Handbook of Mat. Med. Phar. and Thera. 7th Ed. 5.00
White and Wilcox. Mat. Med., Pharmacy, Pharmacology, and Therap. 4th Ed. 3.00

THROAT AND NOSE.

Cohen. Throat and Voice. .40
Hall. Nose and Throat. - ——
Hollopeter. Hay Fever. 1.00
Knight. Throat. Illus. - ——
Mackenzie. Throat Hospital Pharmacopœia. 5th Ed. 1.00
McBride. Clinical Manual, Colored Plates. 2d Ed. - 6.00
Potter. Stammering, etc. 1.00

URINE & URINARY ORGANS.

Acton. Repro. Organs. 1.75
Beale. Urin. Deposits. Plates. 2.00
Holland. The Urine, Milk and Common Poisons. 6th Ed. 1.00
Kleen. Diabetes. - - 2.50
Memminger. Diagnosis by the Urine. 2d Ed. Illus. 1.00
Morris. Renal Surgery. 2.00
Moullin. The Prostate. - 1.75
——— The Bladder. - 1.50
Scott. Clinical and Micros. Examination of Urine. - 5.00
Tyson. Exam. of Urine. 1.25
Van Nüys. Urine Analysis. 1.00

VENEREAL DISEASES.

Cooper. Syphilis. 2d Ed. - 5.00
Gowers. Syphilis and the Nervous System. - - 1.00
Jacobson. Diseases of Male Organs. Illustrated. - 6.00
Sturgis. Manual of. 7th Ed. ——

VISITING LISTS.

Lindsay and Blakiston's Regular Edition. $1.00 to 2.25
——— Perpetual Ed. $1.25 to 1.50
——— Monthly Ed. .75 to 1.00

Digitized by Google

BASED ON RECENT MEDICAL LITERATURE

Gould's Medical Dictionaries

BY GEORGE M. GOULD, A.M., M.D.

Editor "Philadelphia Medical Journal"; President, 1893-94, American Academy of Medicine

THE STANDARD MEDICAL REFERENCE BOOKS

The Illustrated Dictionary of Medicine, Biology, and Allied Sciences

Including the Pronunciation, Accentuation, Derivation, and Definition of the Terms Used in Medicine and those Sciences Collateral to it: Biology (Zoology and Botany), Chemistry, Dentistry, Pharmacology, Microscopy, etc. With many Useful Tables and numerous Fine Illustrations. Large, Square Octavo. 1633 pages. Fifth Edition, now ready.

Full Sheep or Half Dark-Green Leather, $10.00; with Thumb Index, $11.00; Half Russia, Thumb Index, $12.00

The Student's Medical Dictionary. Tenth Edition

Including all the Words and Phrases generally used in Medicine, with their Proper Pronunciation and Definition, Based on Recent Medical Literature. With Tables of the Bacilli, Micrococci, Leukomains, Ptomains, etc., of the Arteries, Muscles, Nerves, Ganglia, and Plexuses; Mineral Springs of the U. S., etc. Small Octavo. 700 pages.

Half Dark Leather, $3.25; Half Morocco, Red Thumb Index, $4.00

This edition has been completely rewritten, and is greatly enlarged and improved over former editions

"We know of but one true way to test the value of a dictionary, and that is to use it. We have used the volume before us as much as opportunity would permit, and in our search have never suffered disappointment. The definitions are lucid and concise, and are framed in the terms supplied by the latest authoritative literature, rather than by purely philological method. Obsolete words are omitted, and this has made the dimensions of the book convenient and compact. In making a dictionary, the author confesses that he has found out the labor consists in eliminating the useless, rather than adding the superfluous. The value of the work before us is increased by the large number of useful reference tables in anatomy, ptomains, micrococci, etc."—*The Physician and Surgeon, Ann Arbor.*

The Pocket Pronouncing Medical Lexicon

FOURTH EDITION, REVISED AND ENLARGED. JUST READY

30,000 WORDS PRONOUNCED AND DEFINED

Giving the Pronunciation and Definition of the Principal Words used in Medicine and the Collateral Sciences, including Very Complete Tables of Clinical Eponymic Terms, of the Arteries, Muscles, Nerves, Bacteria, Bacilli, Micrococci, Spirilla, and Thermometric Scales, and a Dose-list of Drugs and their Preparations, in both the English and Metric Systems of Weights and Measures. Arranged in a most convenient form for reference and memorizing. New Edition. *The System of Pronunciation in this book is very simple.* Thin 64mo. 838 pages.

Full Limp Leather, Gilt Edges, $1.00; Thumb Index, $1.25

These books may be ordered through any bookseller, or upon receipt of price the publishers will deliver free to the purchaser's address. *Full descriptive circulars and sample pages sent free upon application.*

100,000 COPIES OF GOULD'S DICTIONARIES HAVE BEEN SOLD

Digitized by Google

☞ **All prices are net. No discount can be allowed retail purchasers.**

P. BLAKISTON'S SON & CO.'S

Medical and Scientific Publications,

No. 1012 WALNUT ST., PHILADELPHIA.

Acton. The Functions and Disorders of the Reproductive Organs

in Childhood, Youth, Adult Age, and Advanced Life, considered in their Physiological, Social, and Moral Relations. By WM. ACTON, M.D., M.R.C.S. 8th Edition. Cloth, $1.75

Allen. Commercial Organic Analysis.

New Revised Editions. A Treatise on the Properties, Proximate Analytical Examination and Modes of Assaying the Various Organic Chemicals and Products employed in the Arts, Manufactures, Medicine, etc., with Concise Methods for the Detection and Determination of Impurities, Adulterations, and Products of Decomposition, etc. Revised and Enlarged. By ALFRED H. ALLEN, F.C.S., Public Analyst for the West Riding of Yorkshire; Past President Society of Public Analysts of Great Britain.

VOL. I. Preliminary Examination of Organic Bodies. Alcohols, Neutral Alcoholic Derivatives, Ethers, Starch and its Isomers, Sugars, Acid Derivatives of Alcohols and Vegetable Acids, etc. Third Edition, with numerous additions by the author, and revisions and additions by DR. HENRY LEFFMANN, Professor of Chemistry and Metallurgy in the Pennsylvania College of Dental Surgery, and in the Wagner Free Institute of Science, Philadelphia, etc. With many useful tables. 8vo. Cloth, $4.50

VOL. II—PART I. Fixed Oils, Fats, Waxes, Glycerin, Soaps, Nitroglycerin, Dynamite and Smokeless Powders, Wool-Fats, Dégras, etc. Third Edition, with many useful tables. Revised by DR. HENRY LEFFMANN, with numerous additions by the author. 8vo. Cloth, $3.50

VOL. II—PART II. Hydrocarbons, Mineral Oils, Lubricants, Asphalt, Benzene, and Naphthalene, Phenols, Creosote, etc. Third Edition, Revised by DR. HENRY LEFFMANN, with additions by the author. *Just Ready.* Cloth, $3.50

VOL. II—PART III. Terpenes, Essential Oils, Resins, Camphors, Aromatic Acids, etc. Third Edition. *In Preparation.*

VOL. III—PART I. Tannins, Dyes, and Coloring Matters. Third Edition, Revised by I. MERRITT MATTHEWS, Professor of Chemistry and Dyeing at the Philadelphia Textile School. With many additions by the author. *Nearly Ready.*

VOL. III—PART II. The Amines and Ammonium Bases, Hydrazines and Derivatives. Bases from Tar. The Antipyretics, etc. Vegetable Alkaloids, Tea, Coffee, Cocoa, Kola, Cocaïne, Opium, etc. Second Edition. 8vo. Cloth, $4.50

VOL. III—PART III. Vegetable Alkaloids concluded, Non-Basic Vegetable Bitter Principles. Animal Bases, Animal Acids, Cyanogen and its Derivatives, etc. Second Edition. 8vo. Cloth, $4.50

VOL. IV. The Proteids and Albuminous Principles. Proteoïds or Albuminoïds. Second Edition, with elaborate appendices and a large number of useful tables. 8vo. Cloth, $4.50

Ballou. Veterinary Anatomy and Physiology.

By WM. R. BALLOU, M.D., late Professor of Equine Anatomy, New York College of Veterinary Surgeons; Physician to Bellevue Dispensary, and Lecturer on Genito-Urinary Surgery, New York Polyclinic, etc. With 29 Graphic Illustrations. 12mo. *No. 12 ? Quiz-Compend? Series.* Cloth, .80; Interleaved for the Addition of Notes, $1.25

Digitized by Google

Barrett. Dental Surgery

for General Practitioners and Students of Medicine and Dentistry. Extraction of Teeth, etc. By A. W. BARRETT, M.D. Third Ed. 86 Illus. 12mo. Cloth, $1.00

Bartley. Medical and Pharmaceutical Chemistry.

Fifth Edition. A Text-Book for Medical and Pharmaceutical Students. By E. H. BARTLEY, M.D., Professor of Chemistry and Toxicology at the Long Island College Hospital; Dean and Professor of Chemistry, Brooklyn College of Pharmacy; President of the American Society of Public Analysts; Chief Chemist, Board of Health of Brooklyn, N. Y. Revised and Improved. With Illustrations, Glossary, and Complete Index. 12mo. Cloth, $3.00; Leather, $3.50

Clinical Chemistry.

The Chemical Examination of the Saliva, Gastric Juice, Feces, Milk, Urine, etc., with Notes on Urinary Diagnosis, Volumetric Analysis, and Weights and Measures. Illustrated. 12mo. Cloth, $1.00

Beale. On Slight Ailments.

Their Nature and Treatment. By LIONEL S. BEALE, M.D., F.R.S., Professor of Practice, King's Medical College, London. Second Edition. 8vo. Cloth, $1.25

One Hundred Urinary Deposits

on eight sheets, for the Hospital, Laboratory, or Surgery. New Edition. Quarto. Paper, $2.00

Beasley's Book of Prescriptions.

Containing over 3100 Prescriptions, collected from the Practice of the most Eminent Physicians and Surgeons—English, French, and American; a Compendious History of the Materia Medica, Lists of the Doses of all Officinal and Established Preparations, and an Index of Diseases and their Remedies. By HENRY BEASLEY. Seventh Edition. Cloth, $2.00

Druggists' General Receipt Book.

Comprising a copious Veterinary Formulary; Recipes in Patent and Proprietary Medicines, Druggists' Nostrums, etc.; Perfumery and Cosmetics; Beverages, Dietetic Articles, and Condiments; Trade Chemicals, Scientific Processes, and an Appendix of Useful Tables. Tenth Edition. Cloth, $2.00

Pharmaceutical Formulary

and Synopsis of the British, French, German, and United States Pharmacopœias. Comprising Standard and Approved Formulæ for the Preparations and Compounds Employed in Medical Practice. Twelfth Edition. Cloth, $2.00

Beevor. Diseases of the Nervous System and Their Treatment.

By CHAS. EDWARD BEEVOR, M.D., F.R.C.P., Physician to the National Hospital for Paralyzed and Epileptic; formerly Assistant Physician University College Hospital, London. Illustrated. 12mo. Cloth, $2.50

Biddle's Materia Medica and Therapeutics. Thirteenth Edition.

Including Dose List, Dietary for the Sick, Table of Parasites, and Memoranda of New Remedies. By Prof. JOHN B. BIDDLE, M.D., late Professor of Materia Medica in Jefferson Medical College, Philadelphia. Thirteenth Edition, Revised by CLEMENT BIDDLE, M.D., Assistant Surgeon U. S. Navy. With 64 Illustrations and a Clinical Index. Octavo. Cloth, $4.00; Sheep, $5.00

Digitized by Google

Bigelow. Plain Talks on Medical Electricity and Batteries.

With a Therapeutic Index and a Glossary. By HORATIO R. BIGELOW, M.D. With 43 Illustrations and a Glossary. Second Edition. Cloth, $1.00

Birch. Practical Physiology.

An Elementary Class-Book. Including Histology, Chemical and Experimental Physiology. By DE BURGH BIRCH, M.D., C.M., F.R.S.E., Professor of Physiology in the Yorkshire College of the Victoria University, etc. 62 Illus. 12mo. Cloth, $1.75

Black. Micro-Organisms.

The Formation of Poisons. A Biological Study of the Germ Theory of Disease. By G. V. Black, M.D., D.D.S. Cloth, .75

Blackburn. Autopsies. Illustrated.

A Manual of Autopsies, Designed for the Use of Hospitals for the Insane and other Public Institutions. By I. W. BLACKBURN, M.D., Pathologist to the Government Hospital for the Insane. Illustrated. Cloth, $1.25

Bloxam. Chemistry (Inorganic and Organic).

With Experiments. By CHARLES L. BLOXAM. Edited by J. M. THOMPSON, Professor of Chemistry in King's College, London, and A. G. BLOXAM, Head of the Chemistry Department, Goldsmith's Institute, London. Eighth Edition, Revised and Enlarged. 281 Engravings. 8vo. Cloth, $4.25; Leather, $5.25

Bracken. Outlines of Materia Medica and Pharmacology.

By H. M. BRACKEN, Professor of Materia Medica and Therapeutics and of Clinical Medicine, University of Minnesota. 8vo. Cloth, $2.75

Bramwell. Anæmia and Some of the Diseases of the Blood-forming Organs and Ductless Glands.

By BYROM BRAMWELL, M.D., F.R.C.P. (Ed.), Lecturer on the Principles and Practice of Medicine and on Clinical Medicine in the School of the Royal Colleges, Edinburgh, etc. Octavo. Cloth, $2.50

Broomell. Anatomy and Histology of the Human Mouth and Teeth. Illustrated.

By DR. I. N. BROOMELL, Professor of Dental Anatomy, Dental Histology, and Prosthetic Technics in the Pennsylvania College of Dental Surgery. 284 handsome Illustrations, the majority of which are original. Large Octavo. Cloth, $4.50

Brown. Medical Diagnosis. Fourth Edition.

A Manual of Clinical Methods. By J. J. GRAHAM BROWN, M.D., F.R.C.P., Assistant Physician Royal Infirmary; Lecturer on Principles and Practice of Medicine in the School of Medicine of the Royal Colleges, Edinburgh, etc. Fourth Edition. 112 Illustrations. 12mo. Cloth, $2.25

Brown. Elementary Physiology for Nurses.

By MISS FLORENCE H. BROWN, late in charge Nurse Department, St. Thomas' Hospital, London. Illustrated. Cloth, .75

Brubaker. Compend of Physiology. Ninth Edition.

A Compend of Physiology, specially adapted for the use of Students and Physicians. By A. P. BRUBAKER, M.D., Adjunct-Professor of Physiology at Jefferson Medical College; Professor of Physiology, Pennsylvania College of Dental Surgery, Philadelphia. Ninth Edition, Revised, Enlarged, and Illustrated. *No. 4 ? Quiz-Compend ? Series.* 12mo. Cloth, .80; Interleaved, $1.25

Digitized by Google

Bulkley. The Skin in Health and Disease.

By L. DUNCAN BULKLEY, M.D., Attending Physician at the New York Hospital. Illustrated. Cloth, .40

Burnet. Foods and Dietaries.

A Manual of Clinical Dietetics. By R. W. BURNET, M.D., M.R.C.P., Physician to the Great Northern Central Hospital. With Appendix on Predigested Foods and Invalid Cookery. Full Directions as to Hours of Taking Nourishment, Quantity, etc. Third Edition. Cloth, $1.50

Burnett. Hearing, and How to Keep It.

By CHAS. H. BURNETT, M.D., Professor of Diseases of the Ear at the Philadelphia Polyclinic. Illustrated. Cloth, .40

Buxton. On Anesthetics.

A Manual. By DUDLEY WILMOT BUXTON, M.R.C.S., M.R.C.P., Assistant to Professor of Medicine and Administrator of Anesthetics, University College Hospital, London. Third Edition, Illustrated. 12mo. Cloth, $1.50

Butlin. The Operative Surgery of Malignant Disease.

By HENRY T. BUTLIN, F.R.C.S., Assistant Surgeon to, and Demonstrator of Surgery at, St. Bartholomew's Hospital, London, etc., assisted by JAMES BERRY, F.R.C.S., WM. BRUCE-CLARKE, M.B., F.R.C.S., A. H. G. DORAN, F.R.C.S., PERCY FURNIVALL, F.R.C.S., W. H. H. JESSOP, M.B., F.R.C.S., and H. J. WARING, B.Sc., F.R.C.S. Second Ed., Revised and Rewritten. Illus. *Just Ready.* Octavo. Cloth, $4.50

Byford. Manual of Gynecology. 341 Illustrations.

A Practical Student's Book. By HENRY T. BYFORD, M.D., Professor of Gynecology and Clinical Gynecology in the College of Physicians and Surgeons of Chicago; Professor of Clinical Gynecology, Women's Medical School of Northwestern University, and in Post-Graduate Medical School of Chicago, etc. Second Edition, Enlarged. With 341 Illustrations, many of which are from original drawings and several of which are Colored. 12mo. 596 pages. Cloth, $3.00

Caldwell. Chemical Analysis.

Elements of Qualitative and Quantitative Chemical Analysis. By G. C. CALDWELL, B.S., PH.D., Professor of Agricultural and Analytical Chemistry in Cornell University, Ithaca, New York, etc. Third Edition, Revised and Enlarged. Octavo. Cloth, $1.50

Cameron. Oils and Varnishes.

A Practical Handbook. By JAMES CAMERON, F.I.C. With Illustrations, Formulæ, Tables, etc. 12mo. Cloth, $2.25

Soap and Candles.

A Handbook for Manufacturers, Chemists, Analysts, etc. 54 Illustrations. 12mo. Cloth, $2.00

Canfield. Hygiene of the Sick-Room.

A book for Nurses and others. Being a Brief Consideration of Asepsis, Antisepsis, Disinfection, Bacteriology, Immunity, Heating and Ventilation, and kindred subjects, for the Use of Nurses and other Intelligent Women. By WILLIAM BUCKINGHAM CANFIELD, A.M., M.D., late Lecturer on Clinical Medicine, University of Maryland; Physician to Bay View Hospital, Baltimore. 12mo. Cloth, $1.25

Digitized by Google

Carpenter. The Microscope and Its Revelations.

By W. B. CARPENTER, M.D., F.R.S. Eighth Edition, by REV. DR. DALLINGER, F.R.S. Revised and Enlarged, with 800 Illustrations and many Lithographs. Octavo. *Preparing.*

Cautley. Feeding of Infants and Young Children

by Natural and Artificial Methods. By EDMUND CAUTLEY, M.D., Physician to the Belgrave Hospital for Children, London. 12mo. Cloth, $2.00

Cazeaux and Tarnier's Midwifery. With Appendix, by Mundé.

The Theory and Practice of Obstetrics, including the Diseases of Pregnancy and Parturition, Obstetrical Operations, etc. By P. CAZEAUX. Remodeled, rearranged, and revised by S. TARNIER, M.D. Eighth American from the Eighth French and First Italian Edition. Edited by ROBERT J. HESS, M.D., Physician to the Northern Dispensary, Philadelphia, etc. With an Appendix by PAUL F. MUNDÉ, M.D., Professor of Gynecology at the New York Polyclinic. Illustrated by Lithographs, Full-page Plates, and numerous Engravings. 8vo. Cloth, $4.50; Full Leather, $5.50

Clowes and Coleman. Quantitative Analysis.

Adapted for the Use of the Laboratories of Schools and Colleges. By FRANK CLOWES, D.Sc., Emeritus Professor of Chemistry, University College, Nottingham, and I. BERNARD COLEMAN, Assoc. R. C. Sci., Dublin, Professor of Chemistry, Southwest London Polytechnic. Fifth Edition. 117 Illustrations. *Nearly Ready.*

Coblentz. Manual of Pharmacy.

A Text-Book for Students. By VIRGIL COBLENTZ, A.M., PH.D., F.C.S., Professor of Chemistry and Physics; Director of Pharmaceutical Laboratory, College of Pharmacy of the City of New York. Second Edition, Revised and Enlarged. 437 Illustrations. Octavo. 572 pages. Cloth, $3.50; Sheep, $4.50; Half Russia, $5.50

The Newer Remedies.

Including their Synonyms, Sources, Methods of Preparation, Tests, Solubilities, and Doses as far as known. Together with Sections on Organo-Therapeutic Agents and Indifferent Compounds of Iron. Third Edition, very much enlarged. Octavo. Cloth, $1.00

Cohen. System of Physiologic Therapeutics. Illustrated.

A Practical Exposition of the Methods Other than Drug-giving, Useful in the Treatment of the Sick. Edited by SOLOMON SOLIS-COHEN, A.M., M.D., Professor of Medicine and Therapeutics in the Philadelphia Polyclinic; Lecturer on Clinical Medicine at Jefferson Medical College; Physician to the Philadelphia and Rush Hospitals; formerly Lecturer on Therapeutics, Dartmouth Medical College. To be issued in Nine Compact Octavo Volumes of about 300 pages each. *Nearly Ready.*

Mechanotherapy.

By JOHN KEARSLEY MITCHELL, M.D., Assistant Physician to the Orthopedic Hospital and Infirmary for Nervous Diseases; Assistant Neurologist Presbyterian Hospital, Philadelphia; Attending Physician to the Pennsylvania School for Feeble-minded Children; Fellow College of Physicians of Philadelphia, etc.; formerly Lecturer on Symptomology at the University of Pennsylvania; and LUTHER GULICK, M.D., of Springfield, Mass., Member American Association for Advancement of Physical Education, Massachusetts Medical Society, etc.

Rest—Hypnotism—Mental Therapeutics.

By FRANCIS X. DERCUM, M.D., Clinical Professor of Nervous Diseases in Jefferson Medical College; Neurologist to the Philadelphia Hospital; Consulting Physician to the State Asylum for the Chronic Insane at Wernersville, Penna.; Consulting Neurologist to St. Agnes' Hospital; Neurologist to the Jewish Hospital of Philadelphia.

Digitized by Google

Cohen. Physiologic Therapeutics.—Continued.

Electrotherapy.

By GEORGE W. JACOBY, M.D., New York, Consulting Neurologist to the German Hospital, to the Infirmary for Women and Children, to the Craig Colony for Epileptics, etc: Special articles by EDWARD JACKSON, A.M., M.D., Denver, Col.; Emeritus Professor of Diseases of the Eye in the Philadelphia Polyclinic; Member American Ophthalmological Society; Fellow and ex-President American Academy of Medicine, etc.—By J. SOLIS-COHEN, M.D., Emeritus Professor of Diseases of the Throat, Philadelphia Polyclinic; Honorary Professor of Laryngology, Jefferson Medical College; Physician to Hospital for Diseases of the Lungs, Chestnut Hill, etc.—By J. CHALMERS DA COSTA, M.D., Clinical Professor of Surgery in Jefferson Medical College; Surgeon to the Philadelphia and to St. Joseph's Hospitals, etc.—By FRANKLIN H. MARTIN, M.D., Professor of Gynecology, Post-Graduate Medical School of Chicago; Gynecologist Chicago Charity Hospital; Chairman Section of Obstetrics and Diseases of Women of the American Medical Association (1895), etc.

Climatology and Health Resorts, Including Mineral Springs.

By F. PARKES WEBER, M.A., M.D., F.R.C.P. (Lond.), Physician to the German Hospital, Dalston; Assistant Physician North London Hospital for Consumption; Author of "The Mineral Waters and Health Resorts of Europe;" and GUY HINSDALE, A.M., M.D., Secretary of the American Climatological Association; President of the Pennsylvania Society for the Prevention of Tuberculosis; formerly Lecturer on Medical Climatology in the University of Pennsylvania, etc.

Hydrotherapy—Thermotherapy—Balneology.

By DR. WILHELM WINTERNITZ, Professor of Clinical Medicine in the University of Vienna; Director of the General Polyclinic in Vienna, etc.; and DR. E. HEINRICH KISCH, Professor in the University of Prague; Physician at Marienbad Spa.

Pneumotherapy and Inhalation Methods.

By P. TESSIER, of Paris.

Alimentotherapy.

By NATHAN S. DAVIS, JR., A.M., M.D., Professor of Principles and Practice of Medicine in Northwestern University Medical School; Physician to Mercy Hospital, Chicago; Member American Academy of Medicine, American Climatological Society, etc.

Prophylaxis—Personal Hygiene—Nursing and Care of the Sick.

By HAROLD C. ERNST, M.D., Professor of Bacteriology in the Medical School of Harvard University, Boston.

Serotherapy—Organotherapy—Blood-Letting, etc. Indexes.

By JOSEPH MCFARLAND, M.D., Professor of Pathology in the Medico-Chirurgical College, Philadelphia; Pathologist to the Medico-Chirurgical Hospital and to the Rush Hospital for Consumptives and Allied Diseases, etc.—O. T. OSBORNE, M.D., Professor of Materia Medica and Therapeutics, Medical Department, Yale University, New Haven.—FREDERICK A. PACKARD, M.D., Visiting Physician to the Philadelphia and Children's Hospitals and to the Out-patient Department, Pennsylvania Hospital.—The Editor, and AUGUSTUS A. ESHNER, M.D., Professor of Clinical Medicine in the Philadelphia Polyclinic; Physician to the Philadelphia Hospital, etc.

*** These volumes are all in active preparation, several being nearly ready for publication.

Digitized by Google

Cohen. The Throat and Voice.

By J. SOLIS-COHEN, M.D. Illustrated. 12mo. Cloth, .40

Collie. On Fevers.

A Practical Treatise on Fevers, Their History, Etiology, Diagnosis, Prognosis, and Treatment. By ALEX. COLLIE, M.D., M.R.C.P., Medical Officer of the London Fever Hospitals. With Colored Plates. 12mo. Cloth, $2.00

Cooper. Syphilis. Colored Plate.

By ALFRED COOPER, F.R.C.S., Senior Surgeon to St. Mark's Hospital; late Surgeon to the London Lock Hospital, etc. Second Edition, Edited by EDWARD COTTERELL, F.R.C.S., Surgeon London Lock Hospital, etc. 20 Full-page Plates containing many Colored Figures. Octavo. Cloth, $5.00

Coplin. Manual of Pathology. Third Edition. 330 Illustrations.

Including Bacteriology, the Technic of Post-mortems, and Methods of Pathologic Research. By W. M. LATE COPLIN, M.D., Professor of Pathology and Bacteriology, Jefferson Medical College; Pathologist to Jefferson Medical College Hospital and to the Philadelphia Hospital; Bacteriologist to the Pennsylvania State Board of Health. Third Edition, Rewritten and Enlarged. 330 Illustrations, many of which are original, and 7 Colored Plates. 12mo. *Just Ready.* Cloth, $3.50

Practical Hygiene.

With an Introduction by PROF. H. A. HARE, and Articles on Plumbing, Ventilation, etc., by Mr. W. P. LOCKINGTON. 138 Illustrations. 8vo. Second Edition. *In Preparation.*

Cripps. Ovariotomy and Abdominal Surgery.

By HARRISON CRIPPS, F.R.C.S., Surgical Staff, St. Bartholomew's Hospital, London. With 17 Plates, several of which are Colored, and 115 other Illustrations. Large Octavo. Cloth, $8.00

Crocker. Diseases of the Skin.

Their Description, Pathology, Diagnosis, and Treatment, with Special Reference to the Skin Eruptions of Children. By H. RADCLIFFE CROCKER, M.D., Physician to the Department of Skin Diseases, University College Hospital, London. 92 Illustrations. Third Edition. *Preparing.*

Cuff. Lectures on Medicine to Nurses.

By HERBERT EDMUND CUFF, M.D., late Assistant Medical Officer, Stockwell Fever Hospital, England. Second Edition, Revised. With 25 Illustrations. Cloth, $1.25

Dalby. Diseases and Injuries of the Ear.

By SIR WILLIAM B. DALBY, M.D., Aural Surgeon to St. George's Hospital, London. Fourth Edition. With 38 Wood Engravings and 8 Colored Plates. Cloth, $2.50

Davis. Alimentotherapy.

See COHEN, Physiologic Therapeutics, page 10.

Davis. A Manual of Obstetrics.

For Physicians and Students. By EDWARD P. DAVIS, M.D., Professor of Obstetrics in the Jefferson Medical College, etc. Third Edition, Revised. Colored and other Illustrations. 12mo. *Preparing.*

Digitized by Google

Davis. Essentials of Materia Medica and Prescription Writing.

By J. AUBREY DAVIS, M.D., late Assistant Demonstrator of Obstetrics and Quiz-Master in Materia Medica, University of Pennsylvania. 12mo. Cloth, $1.50

Domville. Manual for Nurses

and Others Engaged in Attending to the Sick. By ED. J. DOMVILLE, M.D. Eighth Edition, Revised. With Recipes for Sick-room Cookery, etc. 12mo. Cloth, .75

Donders. Refraction. Portrait of Author.

An Essay on the Nature and the Consequences of Anomalies of Refraction. By F. C. DONDERS, M.D., late Professor of Physiology and Ophthalmology in the University of Utrecht. Authorized Translation. Revised and Edited by CHARLES A. OLIVER, A.M., M.D. (Univ. Pa.), one of the Attending Surgeons to the Wills Eye Hospital; one of the Ophthalmic Surgeons to the Philadelphia Hospital, etc. With a Portrait of the Author and a Series of Explanatory Diagrams. Octavo.
Half Morocco, Gilt, $1.25

Da Costa. Clinical Pathology of the Blood. Colored Plates.

A Practical Guide to the Examination of the Blood by Clinical Methods, with Reference to the Diagnosis of Disease. By JOHN C. DA COSTA, JR., M.D., Assistant Demonstrator of Clinical Medicine in the Jefferson Medical College, Philadelphia; Assistant in the Medical Clinic, Jefferson Medical College Hospital; Hæmatologist to the German Hospital. With six Colored Plates and many other Illustrations. Octavo. *In Press.*

Deaver. Surgical Anatomy. 400 Full-page Plates.

A Treatise on Human Anatomy in its Application to the Practice of Medicine and Surgery. By JOHN B. DEAVER, M.D., Surgeon-in-chief to the German Hospital; Surgeon to the Children's Hospital and to the Philadelphia Hospital; Consulting Surgeon to St. Agnes', St. Timothy's, and Germantown Hospitals; formerly Assistant Professor of Applied Anatomy, University of Pennsylvania, etc. With over 400 very handsome Full-page Illustrations engraved from original drawings made by special artists from dissections prepared for the purpose in the dissecting-rooms of the University of Pennsylvania. Three large volumes. Royal square octavo. Sold by Subscription. Orders taken for complete sets only. Description upon Application.
Cloth, $21.00; Half Morocco or Sheep, $24.00; Half Russia, $27.00

"In summing up the general excellences of this remarkable work, we can accord our unqualified praise for the accurate, exhaustive, and systematic manner in which the author has carried out his plan, and we can commend it as a model of its kind, which must be possessed to be appreciated."—*The Medical Record, New York.*

Appendicitis. Second Edition.

Its History, Anatomy, Etiology, Pathology, Symptoms, Diagnosis, Prognosis, Treatment, Complications, and Sequelæ. A Systematic Treatise, with 22 Plates, 10 of which are Colored, drawn specially for this work. Second Edition, Revised and Rewritten. 8vo. *Just Ready.* Cloth, $3.50

Dercum. Rest—Hypnotism—Mental Therapeutics.

See COHEN, Physiologic Therapeutics, page 9.

Duckworth. On Gout. Illustrated.

A Treatise on Gout. By SIR DYCE DUCKWORTH, M.D. (Edin.), F.R.C.P., Physician to, and Lecturer on Clinical Medicine at, St. Bartholomew's Hospital, London. With Chrome-lithographs and Engravings. Octavo. Cloth, $6.00

Digitized by Google

Dührssen. A Manual of Gynecological Practice.

By DR. A. DÜHRSSEN, Privat-Docent in Midwifery and Gynecology in the University of Berlin. Translated from the Fourth German Edition and Edited by JOHN W. TAYLOR, F.R.C.S., Surgeon to the Birmingham and Midlands Hospital for Women; Vice-President of the British Gynecological Society; and FREDERICK EDGE, M.D., M.R.C.P., F.R.C.S., Surgeon to the Wolverhampton and District Hospital for Women. With 105 Illustrations. 12mo. Cloth, $1.50

Dulles. What to Do First In Accidents and Poisoning.

By C. W. DULLES, M.D., Surgeon to the Rush Hospital; formerly Assistant Surgeon 2d Regiment N. G. Pa., etc. Fifth Edition, Enlarged. With new Illustrations. 12mo. Cloth, $1.00

Eckley. Practical Anatomy.

Including a Special Section on the Fundamental Principles of Anatomy. A Manual for the Use of Students in the Dissecting Room. Based upon Morris' Text-Book of Anatomy. By W. T. ECKLEY, M.D., Professor of Anatomy in the College of Physicians and Surgeons; Professor of Anatomy in the Dental Department, Northwestern University, Chicago, etc.; and CORRINNE BUFORD ECKLEY, Professor of Anatomy in the Northwestern University Women's Medical School; Professor of Anatomy in the Chicago School of Anatomy and Physiology, etc. With 340 Illustrations, many of which are Colored. Octavo. Cloth, $3.50; Waterproof, $4.00

Ernst. Prophylaxis—Personal Hygiene—Nursing and Care of the Sick.

See COHEN, Physiologic Therapeutics, page 10.

Fenwick. Guide to Medical Diagnosis.

By SAMUEL FENWICK, M.D., F.R.C.P., Consulting Physician to the London Hospital; and W. S. FENWICK, M.D., M.R.C.P., Physician to the Out-Patients, Evelina Hospital for Children. Eighth Edition, in great part Rewritten, with several New Chapters. 135 Illustrations. Cloth, $2.50

Ulcer of the Stomach and Duodenum.

42 Illustrations. Royal octavo. *Just Ready.* Cloth, $3.50

Fick. Diseases of the Eye and Ophthalmoscopy.

A Handbook for Physicians and Students. By DR. EUGEN FICK, University of Zurich. Authorized Translation by A. B. HALE, M.D., Ophthalmic Surgeon United Hebrew Charities; Consulting Ophthalmic Surgeon Charity Hospital, Chicago; late Vol. Assistant Imperial Eye Clinic, University of Kiel. With a Glossary and 158 Illustrations, many of which are in Colors. 8vo.
Cloth, $4.50; Sheep, $5.50; Half Russia, $6.50

Fillebrown. A Text-Book of Operative Dentistry.

Written by invitation of the National Association of Dental Faculties. By THOMAS FILLEBROWN, M.D., D.M.D., Professor of Operative Dentistry in the Dental School of Harvard University; Member of the American Dental Association, etc. Illustrated. 8vo. Cloth, $2.25

Fowler's Dictionary of Practical Medicine.

By Various Writers. An Encyclopedia of Medicine. Edited by JAMES KINGSTON FOWLER, M.A., M.D., F.R.C.P., Senior Assistant Physician to, and Lecturer on Pathological Anatomy at, the Middlesex Hospital, London. 8vo.
Cloth, $3.00; Half Morocco, $4.00

Digitized by Google

Fullerton. Obstetric Nursing.

By ANNA M. FULLERTON, M.D., Demonstrator of Obstetrics in the Woman's Medical College; Obstetrician and Gynecologist to the Woman's Hospital, Philadelphia, etc. 41 Illustrations. Fifth Edition, Revised and Enlarged. 12mo. Cloth, $1.00

Surgical Nursing.

Comprising the Regular Course of Lectures upon Abdominal Surgery, Gynecology, and General Surgical Conditions delivered at the Training School of the Woman's Hospital, Philadelphia. Third Edition, Revised. 69 Illustrations. 12mo. Cloth, $1.00

Gardner. The Brewer, Distiller, and Wine Manufacturer.

A Handbook for all interested in the Manufacture and Trade of Alcohol and its Compounds. Edited by JOHN GARDNER, F.C.S. Illustrated. Cloth, $1.50

Bleaching, Dyeing, and Calico Printing.

With Formulæ. Illustrated. Cloth, $1.50

Garrod. On Rheumatism.

A Treatise on Rheumatism and Rheumatic Arthritis. By ARCHIBALD EDWARD GARROD, M.A. (Oxon.), M.D., M.R.C.S. (Eng.), Assistant Physician, West London Hospital. Illustrated. Octavo. Cloth, $5.00

Gilliam's Pathology.

The Essentials of Pathology; a Handbook for Students. By D. TOD GILLIAM, M.D., Professor of Physiology, Starling Medical College, Columbus, O. 47 Illustrations. 12mo. Cloth, .75

Goodall and Washbourn. A Manual of Infectious Diseases.

By EDWARD W. GOODALL, M.D. (London), Medical Superintendent Eastern (Fever) Hospital, Homerton, London, etc.; and J. W. WASHBOURN, F.R.C.P., Assistant Physician to Guy's Hospital and Physician to the London Fever Hospital. Illustrated with Charts, Diagrams, and Full-page Plates. Cloth, $3.00

Gould. The Illustrated Dictionary of Medicine, Biology, and Allied Sciences. Fifth Edition.

Being an Exhaustive Lexicon of Medicine and those Sciences Collateral to it: Biology (Zoology and Botany), Chemistry, Dentistry, Pharmacology, Microscopy, etc. By GEORGE M. GOULD, M.D., Editor of *The Philadelphia Medical Journal*; President, 1893–94, American Academy of Medicine, etc. With many Useful Tables and numerous Fine Illustrations. Large, Square Octavo. 1633 pages. Fifth Edition. *Just Ready.* Full Sheep, or Half Dark-Green Leather, $10.00
With Thumb Index, $11.00; Half Russia, Thumb Index, $12.00

"Few persons read dictionaries as Théophile Gautier did—for pleasure; if, however, all dictionaries were as readable as the one under consideration, his taste for this kind of literature would be less singular. . . . The book is excellently printed, and the illustrations are admirably executed. The binding is substantial and even handsome, but the business-like 'get-up' of the book makes it well fitted for use as well as for the adornment of a book-shelf."—*The British Medical Journal, London.*

The Student's Medical Dictionary. Tenth Edition.

Enlarged. Including all the Words and Phrases generally used in Medicine, with their proper Pronunciations and Definitions, based on Recent Medical Literature. With Tables of the Bacilli, Micrococci, Leukomains, Ptomains, etc., of the Arteries, Muscles, Nerves, Ganglia, and Plexuses; Mineral Springs of the U. S., etc. Rewritten, Enlarged, and set from New Type. Small octavo, 700 pages. Half Dark Leather, $3.25; Half Morocco, Thumb Index, $4.00

Digitized by Google

Gould. The Pocket Pronouncing Medical Lexicon. Fourth Edition. (30,000 Medical Words Pronounced and Defined.)

A Student's Pronouncing Medical Lexicon. Containing all the Words, their Definitions and Pronunciations, that the Student generally comes in contact with; also elaborate Tables of the Arteries, Muscles, Nerves, Bacilli, etc., etc.; a Dose List in both English and Metric Systems, **a new table of Clinical Eponymic Terms,** etc., arranged in a most convenient form for reference and memorizing. Thin 64mo. (6 x 3¼ inches.) 838 pages. *The System of Pronunciation used in this book is very simple. A New Edition. Just Ready.*

Full Limp Leather, Gilt Edges, $1.00; Thumb Index, $1.25

"This 'Dictionary' is admirably suited to the uses of the lecture-room, or for the purposes of a medical defining vocabulary—many of the words not yet being found in any other dictionary, large or small, while all of the words are those of the living medical literature of the day."—*The Virginia Medical Monthly.*

*** 100,000 copies of Gould's Dictionaries have been sold.

Sample pages and descriptive circulars of Gould's Dictionaries free upon application.

Borderland Studies.

Miscellaneous Addresses and Essays Pertaining to Medicine and the Medical Profession, and their Relations to General Science. 350 pages. 12mo. Cloth, $2.00

Gould and Pyle. Cyclopedia of Practical Medicine and Surgery. 72 Special Contributors. Illustrated. One Volume.

A Concise Reference Handbook, Alphabetically Arranged, of Medicine, Surgery, Obstetrics, Materia Medica, Therapeutics, and the various specialties, with Particular Reference to Diagnosis and Treatment. Compiled under the Editorial Supervision of DRS. GEORGE M. GOULD and W. L. PYLE. With many Illustrations.

Just Ready. Large Square 8vo. To correspond with Gould's "Illustrated Dictionary."

Full Sheep, or Half Dark-Green Leather, $10.00; With Thumb Index, $11.00

Half Russia, Thumb Index, $12.00

*** The great success of Dr. Gould's "Illustrated Dictionary of Medicine" suggested the preparation of this companion volume, which should be to the physician the same trustworthy handbook in the broad field of general information that the Dictionary is in the more special one of the explanation of words and the statement of facts. The aim has been to provide in a one-volume book all the material usually contained in the large systems and much which they do not contain. Instead of long, discursive papers on special subjects there are short, concise, pithy articles alphabetically arranged, giving the latest methods of diagnosis, treatment, and operating—a working book in which the editors and their collaborators have condensed all that is essential from a vast amount of literature and personal experience.

The illustrations have been selected with care, only those having been used that are of practical value; no effort has been made to overload the book with useless pictures.

The seventy-two special contributors have been selected from all parts of the country in accordance with their fitness for treating special subjects about which they may be considered expert authorities. They are all men of prominence, teachers, investigators, and writers of experience, who give to the book a character unequaled by any other work of the kind.

"The book is a companion volume to Gould's 'Illustrated Dictionary of Medicine,' which every physician should possess. With these two books in his library, every busy physician will save a vast amount of time in having at hand an instant reference cyclopedia covering every subject in surgery and medicine."—*Chicago Medical Recorder.*

Compend of Diseases of the Eye and Refraction.

Including Treatment and Operations, with a Section on Local Therapeutics. With Formulæ, Glossary, and several Tables. Second Edition. 109 Illustrations, several of which are Colored. *No. 8 ? Quiz-Compend ? Series.*

Cloth, .80; Interleaved for Notes, $1.25

Digitized by Google

Gordinier. The Gross and Minute Anatomy of the Central Nervous System. 261 Illustrations.

By H. C. GORDINIER, A.M., M.D., Professor of Physiology and of the Anatomy of the Nervous System in the Albany Medical College; Member American Neurological Association. With 48 Full-page Plates and 213 other Illustrations, a number of which are printed in Colors and many of which are original. Large 8vo.

Handsome Cloth, $6.00; Sheep, $7.00; Half Russia, $8.00

*** It is universally acknowledged that for a proper comprehension of the normal and abnormal activities of an organ a thorough knowledge of its anatomy is absolutely essential. This is particularly true of diseases of the central nervous system, for in no other way can the disease-symptoms be explained. Without this knowledge, clinical and pathological observations are of little avail. This book is not a theoretic and technical student's book, but a useful working supplement to all works upon general practice and neurology, and as such is destined to mark an epoch in medical literature.

*** The illustrations, of which there are a large number, are chiefly from the author's own preparations. They have been reproduced in the very best manner, the publishers' aim being to give results that are scientifically correct and at the same time pleasing to the eye. In order that certain pictures may be more faithfully shown, they have been printed in colors; this will bring out the details perfectly, and enable the student to quickly recognize their relative value. Those illustrations borrowed from others have generally been remade, so that they will harmonize with the general style adopted for the work. In some cases these have been improved upon in details which the originals failed to make clear.

"This is an excellent book on a fascinating subject, and the author deserves the thanks of the English-speaking medical world for his labor in getting it up. There are works enough on general anatomy, and dry enough they are, as we all remember only too well; but the anatomy of the nervous system alone is another matter entirely, for it is one of the most interesting of all subjects of medical study at the same time that it is one of the most difficult. For both of these reasons the subject is deserving of a treatise by itself, and should not be briefly discussed in a few pages of a general work on anatomy or in an introductory chapter of a treatise on diseases of the nervous system."—*The New York Medical Record.*

Gorgas' Dental Medicine.

A Manual of Materia Medica and Therapeutics. By FERDINAND J. S. GORGAS, M.D., D.D.S., Professor of the Principles of Dental Science, Oral Surgery, and Dental Mechanism in the Dental Department of the University of Maryland. Sixth Edition, Revised and Enlarged, with many Formulæ. 8vo.

Cloth, $4.00; Sheep, $5.00; Half Russia, $6.00

Greene. The Medical Examination for Life Insurance.

With Chapters on Sub-standard Risks and Accident Insurance. By CHARLES LYMAN GREENE, M.D., of St. Paul, Clinical Professor of Medicine and Physical Diagnosis in the University of Minnesota. With 107 Illustrations, many of which are original, several being printed in Colors. Octavo. *In Press.*

Griffith's Graphic Clinical Chart.

Designed by J. P. CROZER GRIFFITH, M.D., Instructor in Clinical Medicine in the University of Pennsylvania. *Printed in three colors.* Sample copies free.

Put up in loose packages of 50, .50

Price to Hospitals: 500 copies, $4.00; 1000 copies, $7.50. With name of Hospital printed on, 50 cents extra.

Groff. Materia Medica for Nurses.

With Questions for Self-examination and a very complete Pronouncing Glossary. By JOHN E. GROFF, Pharmacist to the Rhode Island Hospital, Providence. 12mo. 235 pages. Cloth, $1.25

Digitized by Google

Groves and Thorp. Chemical Technology.

A New and Complete Work. The Application of Chemistry to the Arts and Manufactures. Edited by CHARLES E. GROVES, F.R.S., and WM. THORP, B.SC., F.I.C., assisted by many experts. With numerous Illustrations. *Each volume sold separately.*

Vol. I. FUEL AND ITS APPLICATIONS. 607 Illustrations and 4 Plates. Octavo. Cloth, $5.00; Half Morocco, $6.50

Vol. II. LIGHTING. Illustrated. Octavo. Cloth, $4.00; Half Morocco, $5.50

Vol. III. LIGHTING—Continued. *In Press.*

Vol. IV. ELECTRIC LIGHTING. *In Press.*

Gowers. Manual of Diseases of the Nervous System.

A Complete Text-Book. By WILLIAM R. GOWERS, M.D., F.R.S., Physician to National Hospital for the Paralyzed and Epileptic; Consulting Physician, University College Hospital; formerly Professor of Clinical Medicine, University College, etc. Revised and Enlarged. With many new Illustrations. Two volumes. Octavo.

Vol. I. Diseases of the Nerves and Spinal Cord.

Third Edition. Cloth, $4.00; Sheep, $5.00; Half Russia, $6.00

Vol. II. Brain and Cranial Nerves; General and Functional Diseases.

Second Edition. Cloth, $4.00; Sheep, $5.00; Half Russia, $6.00

*** This book has been translated into German, Italian, and Spanish. It is published in London, Milan, Bonn, Barcelona, and Philadelphia.

Syphilis and the Nervous System.

Being a Revised Reprint of the Lettsomian Lectures for 1890, delivered before the Medical Society of London. 12mo. Cloth, $1.00

Diagnosis of Diseases of the Brain.

8vo. Second Edition. Illustrated. Cloth, $1.50

Medical Ophthalmoscopy.

A Manual and Atlas, with Colored Autotype and Lithographic Plates and Woodcuts, comprising Original Illustrations of the changes of the Eye in Diseases of the Brain, Kidney, etc. Third Edition, Revised, with the assistance of R. MARCUS GUNN, F.R.C.S., Surgeon Royal London Ophthalmic Hospital, Moorfields. Octavo. Cloth, $4.00

The Dynamics of Life.

12mo. Cloth, .75

Clinical Lectures.

A Volume of Essays on the Diagnosis, Treatment, etc., of Diseases of the Nervous System. Cloth, $2.00

Epilepsy and Other Chronic Convulsive Diseases.

Second Edition. *In Press.*

Haig. Causation of Disease by Uric Acid.

A Contribution to the Pathology of High Arterial Tension, Headache, Epilepsy, Mental Depression, Gout, Rheumatism, Diabetes, Bright's Disease, Anæmia, etc. By ALEXANDER HAIG, M.A., M.D. (Oxon.), F.R.C.P., Physician to Metropolitan Hospital, London. 65 Illustrations. Fifth Edition. *In Press.*

Diet and Food.

Considered in Relation to Strength and Power of Endurance. Second Edition, Revised. *Just Ready.* Cloth, $1.00

Digitized by Google

Hale. On the Management of Children

in Health and Disease. Cloth, .50

Hall. Compend of General Pathology and Morbid Anatomy.

By H. NEWBERY HALL, PH.G., M.D., Professor of Pathology, Post-Graduate Medical School, Chicago. 91 Illustrations. Second Edition. *No. 15 ? Quiz-Compend ? Series.* *Preparing.*

Hall. Diseases of the Nose and Throat.

By F. DE HAVILLAND HALL, M.D., F.R.C.P. (Lond.), Physician-in-Charge Throat Department, Westminster Hospital; Joint Lecturer on Principles and Practice of Medicine, Westminster Hospital Medical School, etc. Two Colored Plates and 59 Illustrations. Second Edition. *In Preparation.*

Hamilton. Lectures on Tumors

from a Clinical Standpoint. By JOHN B. HAMILTON, M.D., LL.D., late Professor of Surgery in Rush Medical College, Chicago; Professor of Surgery, Chicago Polyclinic; Surgeon Presbyterian Hospital, etc. Third Edition, Revised. With New Illustrations. 12mo. Cloth, $1.25

Hansell and Reber. Muscular Anomalies of the Eye.

By HOWARD F. HANSELL, A.M., M.D., Clinical Professor of Ophthalmology, Jefferson Medical College; Professor of Diseases of the Eye, Philadelphia Polyclinic, etc.; and WENDELL REBER, M.D., Instructor in Ophthalmology, Philadelphia Polyclinic, etc. With 1 Plate and 28 other Illustrations. 12mo. Cloth, $1.50

Hansell and Bell. Clinical Ophthalmology.

By HOWARD F. HANSELL, A.M., M.D., and JAMES H. BELL, M.D. With Colored Plate of Normal Fundus and 120 Illustrations. 12mo. Cloth, $1.50

Hare. Mediastinal Disease.

The Pathology, Clinical History, and Diagnosis of Affections of the Mediastinum other than those of the Heart and Aorta. By H. A. HARE, M.D., Professor of Materia Medica and Therapeutics in Jefferson Medical College. 8vo. Illustrated. Cloth, $2.00

Harlan. Eyesight,

and How to Care for It. By GEORGE C. HARLAN, M.D., Professor of Diseases of the Eye, Philadelphia Polyclinic. Illustrated. Cloth, .40

Harris' Principles and Practice of Dentistry.

Including Anatomy, Physiology, Pathology, Therapeutics, Dental Surgery, and Mechanism. By CHAPIN A. HARRIS, M.D., D.D.S., late President of the Baltimore Dental College; Author of "Dictionary of Medical Terminology and Dental Surgery." Thirteenth Edition, Revised and Edited by FERDINAND J. S. GORGAS, A.M., M.D., D.D.S., Author of "Dental Medicine;" Professor of the Principles of Dental Science, Oral Surgery, and Dental Mechanism in the University of Maryland. 1250 Illustrations. 1180 pages. 8vo.

Cloth, $6.00; Leather, $7.00; Half Russia, $8.00

Dictionary of Dentistry.

Including Definitions of such Words and Phrases of the Collateral Sciences as Pertain to the Art and Practice of Dentistry. Sixth Edition, Rewritten, Revised, and Enlarged. By FERDINAND J. S. GORGAS, M.D., D.D.S., Author of "Dental Medicine;" Editor of Harris' "Principles and Practice of Dentistry;" Professor of Principles of Dental Science, Oral Surgery, and Prosthetic Dentistry in the University of Maryland. Octavo. Cloth, $5.00; Leather, $6.00

Digitized by Google

Harris and Beale. Treatment of Pulmonary Consumption.

By VINCENT DORMER HARRIS, M.D. (Lond.), F.R.C.P., Physician to the City of London Hospital for Diseases of the Chest; Examining Physician to the Royal National Hospital for Diseases of the Chest, Ventnor, etc.; and E. CLIFFORD BEALE, M.A., M.B. (Cantab.), F.R.C.P., Physician to the City of London Hospital for Diseases of the Chest, etc. 12mo. Cloth, $2.50

Hartridge. Refraction.

The Refraction of the Eye. A Manual for Students. By GUSTAVUS HARTRIDGE, F.R.C.S., Consulting Ophthalmic Surgeon to St. Bartholomew's Hospital, etc. 104 Illustrations and Sheet of Test Types. Tenth Edition, Revised and Enlarged by the Author. Cloth, $1.50

On the Ophthalmoscope.

A Manual for Physicians and Students. Third Edition. With Colored Plates and 68 Wood-cuts. 12mo. Cloth, $1.50

Hartshorne. Our Homes.

Their Situation, Construction, Drainage, etc. By HENRY HARTSHORNE, M.D. Illustrated. Cloth, .40

Hatfield. Diseases of Children.

By MARCUS P. HATFIELD, Professor of Diseases of Children, Chicago Medical College. With a Colored Plate. Second Edition. *Being No. 14 ? Quiz-Compend ? Series.* 12mo. Cloth, .80; Interleaved for the Addition of Notes, $1.25

"Dr. Hatfield seems to have most thoroughly appreciated the needs of students, and most excellently has he condensed his matter into available form. It is in accord with the most recent teachings, and while brief and concise, is surprisingly complete. . . . It is free from irritating repetition of questions and answers which mars so many of the compends now in use. Written in systematic form, the consideration of each disease begins with its definition, and proceeds through the usual subheadings to prognosis and treatment, thus furnishing a complete, readable text-book." —*Annals of Gynecology and Pediatry.*

Hedley. Therapeutic Electricity and Practical Muscle Testing.

By W. S. HEDLEY, M.D., M.R.C.S., in charge of the Electrotherapeutic Department of the London Hospital. 99 Illustrations. Octavo. Cloth, $2.50

Heller. Essentials of Materia Medica, Pharmacy, and Prescription Writing.

By EDWIN A. HELLER, M.D., Quiz-Master in Materia Medica and Pharmacy at the Medical Institute, University of Pennsylvania. 12mo. Cloth, $1.50

Heath. Minor Surgery and Bandaging.

By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College, London. Eleventh Edition, Revised and Enlarged. With 158 Illustrations, 62 Formulæ, Diet List, etc. 12mo. Cloth, $1.25

Practical Anatomy.

A Manual of Dissections. Eighth London Edition. 300 Illus. Cloth, $4.25

Injuries and Diseases of the Jaws.

Fourth Edition, Edited by HENRY PERCY DEAN, M.S., F.R.C.S., Assistant Surgeon London Hospital. With 187 Illustrations. 8vo. Cloth, $4.50

Lectures on Certain Diseases of the Jaws.

Delivered at the Royal College of Surgeons of England, 1887. 64 Illustrations. 8vo. Boards, .50

Digitized by Google

Hemmeter. Diseases of the Stomach. Second Edition.

Their Special Pathology, Diagnosis, and Treatment. With Sections on Anatomy, Analysis of Stomach Contents, Dietetics, Surgery of the Stomach, etc. By JOHN C. HEMMETER, M.D., PHILOS.D., Professor in the Medical Department of the University of Maryland; Consultant to the University Hospital; Director of the Clinical Laboratory, etc.; formerly Clinical Professor of Medicine at the Baltimore Medical College, etc. Second Edition, Enlarged and Thoroughly Revised and in parts Rewritten. With Colored and other Illustrations. *Just Ready.*

Cloth, $6.00; Leather, $7.00; Half Russia, $8.00

*** The rapid sale of the first edition of this book has encouraged the author to revise it very thoroughly and to add much new material (about 100 pages) and a number of new illustrations. About two-thirds of the book has been actually reconstructed. The section on Dietetics will be found particularly useful.

"Dr. Hemmeter certainly provides a book which is well worthy of a careful study. . . . It treats of many subjects in an original manner, and is not only based on a considerable personal experience, but takes due notice of the labors of other well-known workers in this field."—*British Medical Journal.*

Henry. Anæmia.

A Practical Treatise. By FRED'K P. HENRY, M.D., Physician to Episcopal Hospital, Philadelphia. Half Cloth, .50

Hewlett. Manual of Bacteriology.

By R. T. HEWLETT, M.D., M.R.C.P., Assistant Bacteriologist British Institute of Preventive Medicine, etc. With 75 Illustrations. Octavo. Cloth, $3.00

Hollopeter. Hay Fever and Its Successful Treatment.

By W. C. HOLLOPETER, A.M., M.D., Clinical Professor of Pediatrics in the Medico-Chirurgical College of Philadelphia; Physician to the Methodist Episcopal, Medico-Chirurgical, and St. Joseph's Hospitals, etc. Second Edition, Enlarged. 12mo.

Cloth, $1.00

Holden's Anatomy. Seventh Edition.

A Manual of the Dissections of the Human Body. By JOHN LANGTON, F.R.C.S., Surgeon to, and Lecturer on Anatomy at, St. Bartholomew's Hospital. Carefully Revised by A. HEWSON, M.D., Demonstrator of Anatomy, Jefferson Medical College, etc. 300 Illustrations. Two small compact volumes. 12mo. *Preparing.*

Human Osteology.

Comprising a Description of the Bones, with Colored Delineations of the Attachments of the Muscles. The General and Microscopical Structure of Bone and its Development. Eighth Edition, Carefully Revised. Edited by CHARLES STEWART, F.R.S., and R. W. REID, M.D., F.R.C.S. With Lithographic Plates and Numerous Illustrations. Cloth, $5.25

Landmarks.

Medical and Surgical. Fourth Edition. 8vo. Cloth, $1.00

Holland. The Urine, the Gastric Contents, the Common Poisons, and the Milk. Illustrated.

Memoranda (Chemical and Microscopical) for Laboratory Use. By J. W. HOLLAND, M.D., Professor of Medical Chemistry and Toxicology in Jefferson Medical College of Philadelphia. Sixth Edition, Enlarged. Illustrated and Interleaved. 12mo.

Cloth, $1.00

Digitized by Google

Horwitz's Compend of Surgery.

Including Minor Surgery, Amputations, Bandaging, Fractures, Dislocations, Surgical Diseases, and the Latest Antiseptic Rules, etc., with Differential Diagnosis and Treatment. By ORVILLE HORWITZ, B.S., M.D., Professor of Genito-Urinary Diseases, late Demonstrator of Surgery, Jefferson Medical College. Fifth Edition, very much Enlarged and Rearranged. Over 300 pages. 167 Illustrations and 98 Formulæ. 12mo. *No. 9 ? Quiz-Compend ? Series.*

Cloth, .80; Interleaved for Notes, $1.25

*** *A Spanish translation of this book has recently been published in Barcelona.*

Hints on Every Duty of the Surgical Nurse.

Including Antisepsis, Catheterization, Hemorrhage, Shock, Cupping, Leeching, Hypodermic Medication, Bandaging. 43 Illustrations. 12mo. *In Press.*

Horsley. The Brain and Spinal Cord.

The Structure and Functions of. By VICTOR A. HORSLEY, M.B., F.R.S., etc., Assistant Surgeon University College Hospital, London, etc. Illustrated. Cloth, $2.50

Hovell. Diseases of the Ear and Naso-Pharynx.

A Treatise including Anatomy and Physiology of the Organ, together with the treatment of the affections of the Nose and Pharynx which conduce to aural disease. By T. MARK HOVELL, F.R.C.S. (Edin.), M.R.C.S. (Eng.), Aural Surgeon to the London Hospital for Diseases of the Throat, etc. 128 Illus. Second Edition. *Preparing.*

Humphrey. A Manual for Nurses. Seventeenth Edition.

Including General Anatomy and Physiology, Management of the Sick-room, etc. By LAURENCE HUMPHREY, M.A., M.B., M.R.C.S., Assistant Physician to, and Lecturer at, Addenbrook's Hospital, Cambridge, England. Seventeenth Edition. 12mo. Illustrated. Cloth, $1.00

Hughes. Compend of the Practice of Medicine. Sixth Edition.

Giving the Synonyms, Definition, Causes, Symptoms, Pathology, Prognosis, Diagnosis, Treatment, etc., of each Disease. The Treatment is especially full and a number of valuable Prescriptions have been incorporated. Sixth Edition, Revised and Enlarged. By DANIEL E. HUGHES, M.D., Chief Resident Physician Philadelphia Hospital; formerly Demonstrator of Clinical Medicine at Jefferson Medical College, Philadelphia. *Being Nos. 2 and 3 ? Quiz-Compend ? Series.*

Quiz-Compend Edition, in two Parts.

PART I.—Continued, Eruptive, and Periodical Fevers, Diseases of the Mouth, Stomach, Intestines, Peritoneum, Biliary Passages, Liver, Kidneys, Blood, etc., Parasites, etc., and General Diseases, etc.

PART II.—Physical Diagnosis, Diseases of the Respiratory System, Circulatory System, Diseases of the Brain and Nervous System, Mental Diseases, etc.

Price of each Part, in Cloth, .80; Interleaved for the Addition of Notes, $1.25

Physicians' Edition.

In one volume, including the above two parts, a Section on Skin Diseases, and an Index. *Sixth Revised and Enlarged Edition. 625 pages.*

Full Morocco, Gilt Edges, Round Corners, $2.25

Impey. A Handbook on Leprosy.

By S. P. IMPEY, M.D., late Chief and Medical Superintendent, Robben Island Leper and Lunatic Asylums, Cape Colony, South Africa. Illus. Octavo. Cloth, $3.50

Digitized by Google

Ireland. The Mental Affections of Children.

Idiocy, Imbecility, Insanity, etc. By W. W. IRELAND, M.D. (Edin.), of the Home and School for Imbeciles, Mavisbush, Scotland; late Medical Supt. Scot. National Institute for Imbecile Children; Author of "The Blot on the Brain," etc. Second Edition, Revised and Enlarged. *Just Ready.* Cloth, $4.00

Jacobi. Electrotherapy.

See COHEN, Physiologic Therapeutics, page 10.

Jacobson. Operations of Surgery.

By W. H. A. JACOBSON, B.A. (Oxon.), F.R.C.S. (Eng.), Assistant Surgeon Guy's Hospital; Surgeon at Royal Hospital for Children and Women, etc. With over 200 Illustrations. Cloth, $3.00; Leather, $4.00

Diseases of the Male Organs of Generation.

88 Illustrations. Cloth, $6.00

Jessop. Manual of Ophthalmic Surgery and Medicine.

By WALTER H. H. JESSOP, M.D. (Cantab.), F.R.C.S., Ophthalmic Surgeon to, and Lecturer on Ophthalmic Medicine and Surgery at, St. Bartholomew's Hospital, London. 5 Colored Plates, Test Types, and 110 other Illustrations. 12mo. Cloth, $3.00

Jones. Medical Electricity.

A Practical Handbook for Students and Practitioners of Medicine. By H. LEWIS JONES, M.A., M.D., M.R.C.P., Medical Officer in Charge Electrical Department, St. Bartholomew's Hospital. Third Edition of Steavenson and Jones' Medical Electricity, Revised and Enlarged. 112 Illustrations. 12mo. *Preparing.*

Keen. Clinical Charts.

A Series of Seven Outline Drawings of the Human Body, on which may be marked the course of any Disease, Fractures, Operations, etc. By W. W. KEEN, M.D., Professor of the Principles of Surgery and Clinical Surgery, Jefferson Medical College. Put up in pads of 50, with explanations. Each pad, $1.00. Each Drawing may also be had separately gummed on back for pasting in case book. 25 to the pad. Price, 25 cents.

*** *Special Charts will be printed to order. Samples free.*

Kirke's Physiology.

(*15th Authorized Edition. 12mo. Dark Red Cloth.*) A Handbook of Physiology. Fifteenth London Edition, Revised and Enlarged. By W. D. HALLIBURTON, M.D., F.R.S., Professor of Physiology, King's College, London. Thoroughly Revised and in many parts Rewritten. 668 Illustrations, many of which are printed in Colors. 872 pages. 12mo. Cloth, $3.00; Leather, $3.75

IMPORTANT NOTICE. **This is the identical Edition of "Kirke's Physiology," as published in London by John Murray, the sole owner of the book, and containing the revisions and additions of Dr. Halliburton, and the new and original illustrations included at his suggestion. This edition has been carefully and thoroughly revised.**

Kenwood. Public Health Laboratory Work.

By H. R. KENWOOD, M.B., D.P.H., F.C.S., Instructor in Hygienic Laboratory, University College; late Assistant Examiner in Hygiene, Science and Art Department, South Kensington, London, etc. With 116 Illustrations and 3 Plates. Cloth, $2.00

Kleen. Handbook of Massage.

By EMIL KLEEN, M.D., PH.D., Stockholm and Carlsbad. Authorized Translation from the Swedish by EDWARD MUSSEY HARTWELL, M.D., PH.D., Director of Physical Training in the Public Schools of Boston. With an Introduction by Dr. S. WEIR MITCHELL. Illustrated. 8vo. Cloth, $2.25

Digitized by Google

Kleen. Diabetes Mellitus and Glycosuria.

Their Diagnosis and Treatment. See preceding title. Octavo. Cloth, $2.50

Knight. Diseases of the Throat.

A Manual for Students. By CHARLES E. KNIGHT, M.D., Professor of Laryngology, Cornell University Medical College; Surgeon to Throat Department, Manhattan Eye and Ear Hospital, etc. Illustrated. *Nearly Ready.*

Knopf. Pulmonary Tuberculosis. Its Modern Prophylaxis and the Treatment in Special Institutions and at Home.

By S. A. KNOPF, M.D., Physician to the Lung Department of the New York Throat and Nose Hospital; former Assistant Physician to Professor Dettweiler, Falkenstein Sanatorium, Germany, etc. Illustrated. Octavo. Cloth, $3.00

Landis' Compend of Obstetrics.

Especially adapted to the Use of Students and Physicians. By HENRY G. LANDIS, M.D. Sixth Edition, Revised by WM. H. WELLS, M.D., Instructor of Obstetrics, Jefferson Medical College; Member Obstetrical Society of Philadelphia, etc. With 47 Illustrations. *No. 5 ? Quiz-Compend ? Series.*

Cloth, .80; Interleaved for the Addition of Notes, $1.25

Landois. A Text-Book of Human Physiology.

Including Histology and Microscopical Anatomy, with special reference to the requirements of Practical Medicine. By DR. L. LANDOIS, Professor of Physiology and Director of the Physiological Institute in the University of Greifswald. Fifth American translated from the last German Edition, with Additions, by WM. STIRLING, M.D., D.Sc., Brackenbury Professor of Physiology and Histology in Owen's College, and Professor in Victoria University, Manchester; Examiner in Physiology in University of Oxford, England. With 845 Illustrations, many of which are printed in Colors. 8vo. *In Press.*

Lane. Surgery of the Head and Neck.

By L. C. LANE, A.M., M.D., M.R.C.S. (Eng.), Professor of Surgery in Cooper Medical College, San Francisco. Second Edition, with 110 Illus. Octavo. Cloth, $5.00

Lazarus-Barlow. General Pathology.

By W. S. LAZARUS-BARLOW, M.D., Demonstrator of Pathology at the University of Cambridge, England. 795 pages. Octavo. Cloth, $5.00

Lee. The Microtomist's Vade Mecum.

Fifth Edition. A Handbook of Methods of Microscopic Anatomy. By ARTHUR BOLLES LEE, formerly Assistant in the Russian Laboratory of Zoology at Villefranche-sur-Mer (Nice). 887 Articles. Enlarged and Revised, and in many portions greatly extended. 8vo. Cloth, $4.00

Leffmann's Compend of Medical Chemistry.

Inorganic and Organic. Including Urine Analysis. By HENRY LEFFMANN, M.D., Professor of Chemistry in the Woman's Medical College, in the Pennsylvania College of Dental Surgery, and in the Wagner Free Institute of Science, Philadelphia; Pathological Chemist Jefferson Medical College. *No. 10 ? Quiz-Compend ? Series.* Fourth Edition, Rewritten. Cloth, .80; Interleaved for the Addition of Notes, $1.25

The Coal-Tar Colors.

With Special Reference to their Injurious Qualities and the Restrictions of their Use. A Translation of Theodore Weyl's Monograph. 12mo. Cloth, $1.25

Digitized by Google

Leffmann. Examination of Water

for Sanitary and Technical Purposes. Fourth Edition, Enlarged. Illustrated. 12mo. Cloth, $1.25

Analysis of Milk and Milk Products.

Arranged to suit the needs of Analytical Chemists, Dairymen, and Milk Inspectors. Second Edition, Revised and Enlarged. Illustrated. 12mo. Cloth, $1.25

Handbook of Structural Formulæ

for the Use of Students, containing 180 Structural and Stereo-chemic Formulæ. 12mo. Interleaved. Cloth, $1.00

Lewers. On the Diseases of Women.

A Practical Treatise. By DR. A. H. N. LEWERS, Assistant Obstetric Physician to the London Hospital. 146 Engravings. Fifth Edition, Revised. Cloth, $2.50

Lewis (Bevan). Mental Diseases.

A Text-Book having Special Reference to the Pathological Aspects of Insanity. By BEVAN LEWIS, L.R.C.P., M.R.C.S., Medical Director West Riding Asylum, Wakefield, England. 26 Lithograph Plates and other Illustrations. Second Edition, Revised and Enlarged. 8vo. Cloth, $7.00

"It is not merely a reiteration of already recorded and well-known facts, nor is it written with the object of advancing and supporting any special or pet theory. It has for its object rather the endeavor to place on a sounder basis from the anatomical and physiological and pathological standpoints the natural history of the various forms of mental derangement. We may say, in a word, that every page here is bristling with important facts. The book as a whole is worthy of its author and of the great institution over which he presides."—*The Dublin Journal of Medical Science.*

Lincoln. School and Industrial Hygiene.

By D. F. LINCOLN, M.D. Cloth, .40

Longley's Pocket Medical Dictionary.

Giving the Definition and Pronunciation of Words and Terms in General Use in Medicine, with an Appendix, containing Poisons and their Antidotes, Abbreviations Used in Prescriptions, etc. By ELIAS LONGLEY. Cloth, .75; Tucks and Pocket, $1.00

Macalister's Human Anatomy. 816 Illustrations.

Systematic and Topographical, including the Embryology, Histology, and Morphology of Man. With Special Reference to the Requirements of Practical Surgery and Medicine. By ALEX. MACALISTER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge, England. 816 Illustrations. Octavo.
Cloth, $5.00; Leather, $6.00

Mackenzie. The Pharmacopœia of the London Hospital for Diseases of the Throat.

By SIR MORELL MACKENZIE, M.D. Fifth Edition, Revised and Improved by F. G. HARVEY, Surgeon to the Hospital. Cloth, $1.00

Macready. A Treatise on Ruptures.

By JONATHAN F. C. H. MACREADY, F.R.C.S., Surgeon to the Great Northern Central Hospital; to the City of London Hospital for Diseases of the Chest; to the City of London Truss Society, etc. 24 Full-page Plates and Wood Engravings. Octavo.
Cloth, $6.00

Mann. Forensic Medicine and Toxicology.

By J. DIXON MANN, M.D., F.R.C.P., Professor of Medical Jurisprudence and Toxicology in Owens College, Manchester; Examiner in Forensic Medicine in University of London, etc. Illustrated. Octavo. Cloth, $6.50

Digitized by Google

Mann's Manual of Psychological Medicine

and Allied Nervous Diseases. Their Diagnosis, Pathology, Prognosis, and Treatment, including their Medico-Legal Aspects; with Chapter on Expert Testimony, and an Abstract of the Laws Relating to the Insane in all the States of the Union. By EDWARD C. MANN, M.D. With Illustrations. Octavo. Cloth, $3.00

Marshall's Physiological Diagrams, Life Size, Colored.

Eleven Life-size Diagrams (each 7 feet by 3 feet 7 inches). Designed for Demonstration before the Class. By JOHN MARSHALL, F.R.S., F.R.C.S., Professor of Anatomy to the Royal Academy; Professor of Surgery, University College, London, etc. In Sheets, $40.00; Backed with Muslin and Mounted on Rollers, $60.00
Ditto, Spring Rollers, in Handsome Walnut Map Case, $100.00
Single Plates, Sheets, $5.00; Mounted, $7.50; Explanatory Key, 50 cents.
Purchaser must pay freight charges.

No. 1—The Skeleton and Ligaments. No. 2—The Muscles and Joints, with Animal Mechanics. No. 3—The Viscera in Position. The Structure of the Lungs. No. 4—The Heart and Principal Blood-vessels. No. 5—The Lymphatics or Absorbents. No. 6—The Digestive Organs. No. 7—The Brain and Nerves. Nos. 8 and 9—The Organs of the Senses. Nos. 10 and 11—The Microscopic Structure of the Textures and Organs. (*Send for Special Circular.*)

Marshall. The Woman's Medical College of Pennsylvania.

An Historical Outline. By CLARA MARSHALL, M.D., Dean of the College. 8vo. Cloth, $1.50

Mason's Compend of Electricity

and Its Medical and Surgical Uses. By CHARLES F. MASON, M.D., Assistant Surgeon U. S. Army. With an Introduction by CHARLES H. MAY, M.D., Instructor in the New York Polyclinic. Illustrated. 12mo. Cloth, .75

Maxwell. Terminologia Medica Polyglotta.

By DR. THEODORE MAXWELL, assisted by others in various countries. 8vo. Cloth, $3.00

The object of this work is to assist the medical men of any nationality in reading medical literature written in a language not their own. Each term is usually given in seven languages, viz.: English, French, German, Italian, Spanish, Russian, and Latin.

Maylard. The Surgery of the Alimentary Canal.

By ALFRED ERNEST MAYLARD, M.B., B.S., Senior Surgeon to the Victoria Infirmary, Glasgow. Second Edition. 97 Illustrations. Octavo. Cloth, $3.00

Mays' Theine in the Treatment of Neuralgia.

By THOMAS J. MAYS, M.D. 16mo. ½ bound, .50

McBride. Diseases of the Throat, Nose, and Ear.

A Clinical Manual for Students and Practitioners. By P. MCBRIDE, M.D., F.R.C.P. (Edin.), Surgeon to the Ear and Throat Department of the Royal Infirmary; Lecturer on Diseases of Throat and Ear, Edinburgh School of Medicine, etc. With Colored Illustrations from Original Drawings. Second Edition. Octavo. Handsome Cloth, Gilt top, $6.00

McCook. American Spiders and Their Spinning Work.

A Natural History of the Orbweaving Spiders of the United States, with Special Regard to their Industry and Habits. By HENRY C. MCCOOK, D.D., Vice-President of the Academy of Natural Sciences of Philadelphia; Member Entomological Society; Author of "The Agricultural Ants of Texas," etc. Three volumes. Handsomely Illustrated. Cloth, $50.00

Digitized by Google

McNeill. The Prevention of Epidemics and the Construction and Management of Isolation Hospitals.

By DR. ROGER MCNEILL, Medical Officer of Health for the County of Argyll. With Numerous Plans and other Illustrations. Octavo. Cloth, $3.50

Meigs. Milk Analysis and Infant Feeding.

The Examination of Human and Cow's Milk, Cream, Condensed Milk, etc., and Directions as to the Diet of Young Infants. BY ARTHUR V. MEIGS, M.D. 12mo. Cloth, .50

Memminger. Diagnosis by the Urine.

The Practical Examination of Urine, with Special Reference to Diagnosis. By ALLARD MEMMINGER, M.D., Professor of Chemistry and Hygiene; Clinical Professor of Urinary Diagnosis in the Medical College of the State of South Carolina; Visiting Physician in the City Hospital of Charleston, etc. Second Edition, Enlarged and Revised. 24 Illustrations. 12mo. Cloth, $1.00

Montgomery. A Text-Book of Gynecology.

By EDWARD E. MONTGOMERY, M.D., Professor of Gynecology in Jefferson Medical College, Philadelphia, etc. About 500 Illustrations, many of which are from original sources. Octavo. *Nearly Ready.*

*** This is a systematic modern treatise on Diseases of Women. The author's aim has been to produce a book that will be thorough and practical in every particular. The illustrations, nearly all of which are from original sources, have for the most part been drawn by special artists who, for a number of months, have devoted their sole attention to this work.

Morris. Text-Book of Anatomy. Second Edition. 790 Illustrations, many in Colors.

A Complete Text-Book. Edited by HENRY MORRIS, F.R.C.S., Surgeon to, and Lecturer on Anatomy at, Middlesex Hospital, assisted by J. BLAND SUTTON, F.R.C.S., J. H. DAVIES-COLLEY, F.R.C.S., WM. J. WALSHAM, F.R.C.S., H. ST. JOHN BROOKS, M.D., R. MARCUS GUNN, F.R.C.S., ARTHUR HENSMAN, F.R.C.S., FREDERICK TREVES, F.R.C.S., WILLIAM ANDERSON, F.R.C.S., ARTHUR ROBINSON, M.D., M.R.C.S., and PROF. W. H. A. JACOBSON. One Handsome Octavo Volume, with 790 Illustrations, of which many are printed in Colors.

Cloth, $6.00; Leather, $7.00; Half Russia, $8.00

"Of all the text-books of moderate size on human anatomy in the English language, Morris is undoubtedly the most up-to-date and accurate. . . . For the student, the surgeon, or for the general practitioner who desires to review his anatomy, Morris is decidedly the book to buy."—*The Philadelphia Medical Journal.*

"The ever-growing popularity of the book with teachers and students is an index of its value, and it may safely be recommended to all interested."—*The New York Medical Record.*

Handsome circular, with sample pages and colored illustrations, will be sent free to any address.

Renal Surgery.

With Special Reference to Stone in the Kidney and Ureter, and to the Surgical Treatment of Calculous Anuria, together with a Critical Examination of Subparietal Injuries of the Ureter. Illustrated. 8vo. Cloth, $2.00

Mitchell and Gulick. Mechanotherapy.

See COHEN, Physiologic Therapeutics, page 9.

Morton on Refraction of the Eye.

Its Diagnosis and the Correction of its Errors. With Chapter on Keratoscopy and Test Types. By A. MORTON, M.B. Sixth Edition, Revised. Cloth, $1.00

Digitized by Google

Moullin. Surgery. Third Edition, by Hamilton.

A Complete Text-Book. By C. W. MANSELL MOULLIN, M.A., M.D. (Oxon.), F.R.C.S., Surgeon and Lecturer on Physiology to the London Hospital; formerly Radcliffe Traveling Fellow and Fellow of Pembroke College, Oxford. Third American Edition, Revised and Edited by the late JOHN B. HAMILTON, M.D., LL.D., Professor of the Principles of Surgery and Clinical Surgery, Rush Medical College, Chicago; Professor of Surgery, Chicago Polyclinic; Surgeon, formerly Supervising Surgeon-General, U. S. Marine Hospital Service; Surgeon to Presbyterian Hospital. 600 Illustrations, over 200 of which are original, and many of which are printed in Colors. Royal Octavo. 1250 pages.

*** *Circular free.* Cloth, $6.00; Leather, $7.00; Half Russia, $8.00

"The aim to make this valuable treatise practical by giving special attention to questions of treatment has been admirably carried out. Many a reader will consult the work with a feeling of satisfaction that his wants have been understood, and that they have been intelligently met. He will not look in vain for details, without proper attention to which he well knows that the highest success is impossible."—*The American Journal of Medical Sciences.*

Enlargement of the Prostate.

Its Treatment and Radical Cure. Illustrated. Second Edition, Enlarged. Octavo. Cloth, $1.75

Inflammation of the Bladder and Urinary Fever.

Octavo. Cloth, $1.50

Muter. Practical and Analytical Chemistry.

By JOHN MUTER, F.R.S., F.C.S., etc. Second American from the Eighth English Edition. Revised to meet the Requirements of American Medical and Pharmaceutical Colleges. 56 Illustrations. Cloth, $1.25

New Sydenham Society Publications.

From three to six volumes published each year. *List of Volumes upon application.* Per annum, $8.00

Notter and Firth. The Theory and Practice of Hygiene.

A Complete Treatise by J. LANE NOTTER, M.A., M.D., F.C.S., Fellow and Member of Council of the Sanitary Institute of Great Britain; Professor of Hygiene, Army Medical School; Examiner in Hygiene, University of Cambridge, etc.; and R. H. FIRTH, F.R.C.S., Assistant Professor of Hygiene, Army Medical School, Netly. Illustrated by 10 Lithographic Plates and 135 other Illustrations, and including many Useful Tables. Second Edition, Carefully Revised. *In Press.*

Oettel. Practical Exercises in Electro-Chemistry.

By DR. FELIX OETTEL. Authorized Translation by EDGAR F. SMITH, M.A., Professor of Chemistry, University of Pennsylvania. Illustrated. Cloth, .75

Introduction to Electro-Chemical Experiments.

Illustrated. By same Author and Translator. Cloth, .75

Ohlemann. Ocular Therapeutics for Physicians and Students.

By M. OHLEMANN, M.D., late Physician in the Ophthalmological Clinical Institute, Royal Prussian University of Berlin, etc. Translated and Edited by CHARLES A. OLIVER, A.M., M.D., Attending Surgeon to the Wills Eye Hospital; Ophthalmic Surgeon to the Philadelphia and to the Presbyterian Hospitals. 12mo. Cloth, $1.75

Ormerod. Diseases of Nervous System.

By J. A. ORMEROD, M.D. (Oxon.), F.R.C.P., Physician to National Hospital for the Paralyzed and Epileptic, London. 66 Wood Engravings. 12mo. Cloth, $1.00

Digitized by Google

Osgood. The Winter and Its Dangers.

By HAMILTON OSGOOD, M.D. Cloth, .40

Osler. Chorea and Choreiform Affections.

By WILLIAM OSLER, M.D., F.R.C.P. (Lond.), Professor of Medicine, Johns Hopkins University, etc. 8vo. Cloth, $2.00

Ostrom. Massage and the Original Swedish Movements.

Their Application to Various Diseases of the Body. A Manual for Students, Nurses, and Physicians. By KURRE W. OSTROM, from the Royal University of Upsala, Sweden, Instructor in Massage and Swedish Movements in the Hospital of the University of Pennsylvania and in the Philadelphia Polyclinic and College for Graduates in Medicine, etc. Fourth Edition, Enlarged. 105 Illustrations, many of which were drawn especially for this purpose. 12mo. Cloth, $1.00

"In this volume the author gives an excellent description of the methods of massage and Swedish movements, together with their applicability to various diseased conditions of the body. The methods are rapidly becoming popularized in our own country, and the perusal of such a book as Mr. Ostrom has written will be of great advantage to physicians, for whose use it is mainly intended."—*The Journal of the American Medical Association.*

Packard's Sea Air and Sea Bathing.

By JOHN H. PACKARD, M.D. Cloth, .40

Parkes. Hygiene and Public Health.

A Practical Manual. By LOUIS C. PARKES, M.D., D.P.H. (Lond. Univ.), Lecturer on Public Health at St. George's Hospital; Medical Officer of Health, Parish of Chelsea, London, etc. Fifth Edition, Enlarged and Revised. 80 Illustrations. 12mo. Cloth, $2.50

"The style is good; dry facts, laws, and statistics are put in such a way that the reader does not tire of them and yet finds them easy to remember."—*University Medical Magazine, Philadelphia.*

The Elements of Health.

An Introduction to the Study of Hygiene. Illustrated. Cloth, $1.25

Parrish's Alcoholic Inebriety.

From a Medical Standpoint, with Illustrative Cases. By JOSEPH PARRISH, M.D. Cloth, $1.00

Phillips. Spectacles and Eyeglasses.

Their Prescription and Adjustment. By R. J. PHILLIPS, M.D., Instructor in Diseases of the Eye, Philadelphia Polyclinic; Ophthalmic Surgeon, Presbyterian Hospital. Second Edition, Revised and Enlarged. 49 Illustrations. 12mo. Cloth, $1.00

"This little work now appears in the form of a revised second edition. It is of convenient size and is excellently printed. The book is issued as an aid to those who prescribe and who sell eyeglasses and spectacles, for the purpose of enabling them to reach the most satisfactory and beneficial results in the adjustment of lenses to the eyes of patients. Since the proper adjustment of spectacles and eyeglasses is of very great importance, it is desirable that the rules and suggestions contained in this little volume should be familiar to every oculist and optician."—*The Medical Record, New York.*

"This excellent manual, which has received its second edition, continues to be the best book on the subject of which it treats. It should be read by every one who is interested in that most important portion of the ophthalmic surgeon's work—the supervision of the proper adjustment of spectacles. It is doubly useful for those practitioners of ophthalmology who are unable to command the services of a skilled optician."—*The American Journal of the Medical Sciences, Philadelphia.*

Digitized by Google

Physician's Visiting List.

Published Annually. Forty-ninth Year (1900) of its Publication.

Hereafter all styles will contain the interleaf or special memoranda page, except the Monthly Edition, and the sizes for 75 and 100 Patients will come in two volumes only.

REGULAR EDITION.

For 25 Patients	Weekly.				Tucks,	pocket and	pencil,	Gilt	Edges,	$1.00
50	"	"			"	"	"	"	"	1.25
50	"	"	2 vols.	Jan. to June / July to Dec.	"	"	"	"	"	2.00
75	"	"	2 vols.	Jan. to June / July to Dec.	"	"	"	"	"	2.00
100	"	"	2 vols.	Jan. to June / July to Dec.	"	"	"	"	"	2.25

Perpetual Edition,

without Dates and with Special Memorandum Pages.

For 25 Patients, Interleaved, Tucks, Pocket, and Pencil, $1.25
For 50 Patients, Interleaved, Tucks, Pocket, and Pencil, $1.50

Monthly Edition, without Dates.

Can be commenced at any time and used until full. Requires only one writing of patient's name for the whole month.

Plain binding, without Flap or Pencil, .75; Leather cover, Pocket and Pencil, $1.00

Extra Pencils

will be sent, postpaid, for 25 cents per half dozen.

☞ This list combines the several essential qualities of strength, compactness, durability, and convenience. It is made in all sizes and styles to meet the wants of all physicians. It is not an elaborate, complicated system of keeping accounts, but a plain, simple record, that may be kept with the least expenditure of time and trouble—hence its popularity. A special circular, descriptive of contents, will be sent upon application.

Potter. A Handbook of Materia Medica, Pharmacy, and Therapeutics. Seventh Edition.

Including the Action of Medicines, Special Therapeutics of Disease, Official and Practical Pharmacy, and Minute Directions for Prescription Writing, etc. Including over 600 Prescriptions and Formulæ. By SAMUEL O. L. POTTER, M.A., M.D., M.R.C.P. (Lond.), Professor of the Principles and Practice of Medicine and Clinical Medicine in the College of Physicians and Surgeons, San Francisco; Brigade Surgeon U. S. Vol. Seventh Edition, Revised and Enlarged. 8vo.

With Thumb Index in each copy. Cloth, $5.00; Leather, $6.00; Half Russia, $7.00

Compend of Anatomy, including Visceral Anatomy.

Sixth Edition, Revised and greatly Enlarged. With 16 Lithographed Plates and 117 other Illustrations. *Being No. 1 ? Quiz-Compend ? Series.*

Cloth, .80; Interleaved for Taking Notes, $1.25

Compend of Materia Medica, Therapeutics, and Prescription Writing.

With Special Reference to the Physiological Action of Drugs. Sixth Revised and Improved Edition, with Index. *Being No. 6 ? Quiz-Compend ? Series.*

Cloth, .80; Interleaved for Taking Notes, $1.25

Digitized by Google

Potter. Speech and Its Defects.

Considered Physiologically, Pathologically, and Remedially; being the Lea Prize Thesis of Jefferson Medical College, 1882. Revised and Corrected. 12mo.
Cloth, $1.00

Powell. Diseases of the Lungs and Pleuræ, Including Consumption.

By R. DOUGLAS POWELL, M.D., F.R.C.P., Physician to the Middlesex Hospital, and Consulting Physician to the Hospital for Consumption and Diseases of the Chest at Brompton. Fourth Edition. Colored Plates and Wood Engravings. 8vo.
Cloth, $4.00

Power. Surgical Diseases of Children

and their Treatment by Modern Methods. By D'ARCY POWER, M.A., F.R.C.S. (Eng.), Demonstrator of Operative Surgery, St. Bartholomew's Hospital; Surgeon to the Victoria Hospital for Children. Illustrated. 12mo. Cloth, $2.50

Preston. Hysteria and Certain Allied Conditions.

Their Nature and Treatment. With Special Reference to the Application of the Rest Cure, Massage, Electrotherapy, Hypnotism, etc. By GEORGE J. PRESTON, M.D., Professor of Diseases of the Nervous System, College of Physicians and Surgeons, Baltimore; Visiting Physician to the City Hospital; Consulting Neurologist to Bay View Asylum and the Hebrew Hospital; Member American Neurological Association, etc. Illustrated. 12mo. Cloth, $2.00

Pritchard. Handbook of Diseases of the Ear.

By URBAN PRITCHARD, M.D., F.R.C.S., Professor of Aural Surgery, King's College, London; Aural Surgeon to King's College Hospital; Senior Surgeon to the Royal Ear Hospital, etc. Third Edition. Many Illustrations and Formulæ. 12mo.
Cloth, $1.50

Proctor's Practical Pharmacy.

Lectures on Practical Pharmacy. By BARNARD S. PROCTOR. Third Edition, Revised. With Elaborate Tables of Chemical Solubilities, etc. Illustrated. Cloth, $3.00

Reese's Medical Jurisprudence and Toxicology.

A Text-Book for Medical and Legal Practitioners and Students. By JOHN J. REESE, M.D., Editor of "Taylor's Jurisprudence," Professor of the Principles and Practice of Medical Jurisprudence, including Toxicology, in the University of Pennsylvania Medical Department. Fifth Edition, Revised and Edited by HENRY LEFFMANN, M.D., Pathological Chemist, Jefferson Medical College Hospital; Chemist, State Board of Health; Professor of Chemistry, Woman's Medical College of Pennsylvania, etc. 12mo. 645 pages. Cloth, $3.00; Leather, $3.50

"To the student of medical jurisprudence and toxicology it is invaluable, as it is concise, clear, and thorough in every respect."—*The American Journal of the Medical Sciences.*

Reeves. Medical Microscopy.

Including Chapters on Bacteriology, Neoplasms, Urinary Examination, etc. By JAMES E. REEVES, M.D., ex-President American Public Health Association, etc. Numerous Illustrations, some of which are printed in Colors. 12mo. Cloth, $2.50

Régis. Mental Medicine.

A Practical Manual. By DR. E. RÉGIS, formerly Chief of Clinique of Mental Diseases, Faculty of Medicine of Paris; Physician of the Maison de Santé de Castel d'Andorte. With a Preface by M. BENJAMIN BALL, Clinical Professor of Mental Diseases, Faculty of Medicine, Paris. Authorized Translation by H. M. BANNISTER, M.D., late Senior Assistant Physician, Illinois Eastern Hospital for the Insane, etc. With an Introduction by the Author. 12mo. Cloth, $2.00

Digitized by Google

Richardson. Long Life,

and How to Reach It. By J. G. RICHARDSON, formerly Professor of Hygiene, University of Pennsylvania. Cloth, .40

Richardson's Mechanical Dentistry.

A Practical Treatise on Mechanical Dentistry. By JOSEPH RICHARDSON, D.D.S. Seventh Edition, Thoroughly Revised and in many parts Rewritten by GEO. W. WARREN, A.M., D.D.S., Professor of Clinical Dentistry and Oral Surgery; Chief of the Clinical Staff, Pennsylvania College of Dental Surgery, Philadelphia. With 691 Illustrations, many of which are from Original Wood Engravings. Octavo. 675 pages. Cloth, $5.00; Leather, $6.00; Half Russia, $7.00

Roberts. Fractures of the Radius.

A Clinical, Pathological, and Experimental Study. By JOHN B. ROBERTS, M.D., Professor of Anatomy and Surgery in the Philadelphia Polyclinic, etc. 33 Illustrations. 8vo. Cloth, $1.00

Richter's Inorganic Chemistry.

A Text-Book for Students. By PROF. VICTOR VON RICHTER, University of Breslau. Fourth American from Sixth German Edition. Authorized Translation by EDGAR F. SMITH, M.A., PH.D., Professor of Chemistry, University of Pennsylvania, Member of the Chemical Societies of Berlin and Paris. 89 Illustrations and a Colored Plate. 12mo. Cloth, $1.75

Organic Chemistry.

The Chemistry of the Carbon Compounds. Third American Edition, Translated from PROF. ANSCHÜTZ'S Eighth German Edition by EDGAR F. SMITH, M.A., PH.D., Professor of Chemistry, University of Pennsylvania. Revised and Enlarged. Illustrated. 12mo. Two volumes.

Vol. I. Aliphatic Series. 625 pages. Cloth, $3.00
Vol. II. Carbocyclic and Heterocyclic Series. 671 pages. Cloth, $3.00

Robinson. Latin Grammar of Pharmacy and Medicine.

By D. H. ROBINSON, PH.D., Professor of Latin Language and Literature, University of Kansas. Introduction by L. E. SAYRE, PH.G., Professor of Pharmacy and Dean of the Department of Pharmacy in University of Kansas. Third Edition, Revised with the help of PROF. L. E. SAYRE, of University of Kansas, and DR. CHARLES RICE, of the College of Pharmacy of the City of New York. 12mo. Cloth, $1.75

"This method of preparing medical students and pharmacists for a practical use of the language is in every way to be commended. . . . Pharmacists should know enough to read prescriptions readily and understandingly."—*Johns Hopkins Hospital Bulletin.*

"It is practical; its arrangement shows the careful and thoughtful genius of its author, who seems to have comprehended just the need of the student, and put it in such genial form as to lead the pupil rapidly to an understanding of what he had feared would be uninteresting and tedious."—*Pharmaceutical Record.*

St. Clair. Medical Latin.

Designed Expressly for the Elementary Training of Medical Students. By W. T. ST. CLAIR, Instructor in Latin in the Kentucky School of Medicine and in the Louisville Male High School. 12mo. Cloth, $1.00

Sansom. Diseases of the Heart.

The Diagnosis and Pathology of Diseases of the Heart and Thoracic Aorta. By A. ERNEST SANSOM, M.D., F.R.C.P., Physician to the London Hospital, etc. With Illustrations. 8vo. Cloth, $6.00

Digitized by Google

Sayre. Organic Materia Medica and Pharmacognosy.

An Introduction to the Study of the Vegetable Kingdom and the Vegetable and Animal Drugs. Comprising the Botanical and Physical Characteristics, Source, Constituents, Pharmacopœial Preparations; Insects Injurious to Drugs, and Pharmacal Botany. By L. E. SAYRE, B.S., PH.M., Dean of the School of Pharmacy and Professor of Materia Medica and Pharmacy in the University of Kansas; Member Committee of Revision of the United States Pharmacopœia, etc. With Sections on Histology and Microtechnique by WILLIAM C. STEVENS, Professor of Botany in the University of Kansas. Second Edition, Revised and Enlarged. With 374 Illustrations, the majority of which are from Original Drawings. 8vo. Cloth, $4.50

Schamberg. Compend of Diseases of the Skin.

By JAY F. SCHAMBERG, Professor of Diseases of the Skin, Philadelphia Polyclinic; Fellow of the College of Physicians of Philadelphia; Quiz-Master at University of Pennsylvania. 99 Illustrations. Cloth, .80; Interleaved, $1.25

Schreiner. Diet List.

Arranged in the Form of a Chart on which Articles of Diet can be Indicated for any Disease. By E. R. SCHREINER, M.D., Assistant Demonstrator of Physiology, University of Pennsylvania. Put up in Pads of 50 with Pamphlet of Specimen Dietaries. Per Pad, .75

Scott. The Urine: Its Chemical and Microscopical Examination.

By LINDLEY MARCROFT SCOTT, M.A., M.D., etc. With 41 Colored Plates and other Illustrations. Quarto. *Just Ready.* Cloth, $5.00

Scoville. The Art of Compounding. Second Edition.

A Text-Book for Students and a Reference Book for Pharmacists. By WILBUR L. SCOVILLE, PH.G., Professor of Applied Pharmacy and Director of the Pharmaceutical Laboratory in the Massachusetts College of Pharmacy. Second Edition, Enlarged and Improved. Cloth, $2.50; Sheep, $3.50; Half Russia, $4.50

Shuttleworth. Mentally Deficient Children.

Their Treatment and Training. By GEORGE E. SHUTTLEWORTH, M.D., M.R.C.S., Medical Examiner of Defective Children, School Board of London; late Medical Superintendent Royal Albert Asylum for Idiots, etc. Second Edition, Revised. Cloth, $1.50

Smith. Abdominal Surgery. Sixth Edition.

Being a Systematic Description of all the Principal Operations. By J. GREIG SMITH, M.A., F.R.S.E., Surgeon to British Royal Infirmary. 224 Illustrations. Sixth Edition, Enlarged and Thoroughly Revised by JAMES SWAIN, M.D. (Lond.), F.R.C.S., Professor of Surgery, University College, Bristol, etc. Two vols. 8vo. Cloth, $10.00

Smith. Electro-Chemical Analysis.

By EDGAR F. SMITH, Professor of Chemistry, University of Pennsylvania. Second Edition, Revised and Enlarged. 27 Illustrations. 12mo. Cloth, $1.25

*** This book has been translated and published in both Germany and France.

Smith and Keller. Experiments.

Arranged for Students in General Chemistry. By EDGAR F. SMITH, Professor of Chemistry, University of Pennsylvania, and DR. H. F. KELLER, Professor of Chemistry, Philadelphia High School. Third Edition. 8vo. Illustrated. Cloth, .60

Smith. Dental Metallurgy.

A Manual. By ERNEST A. SMITH, F.C.S., Assistant Instructor in Metallurgy, Royal College of Science, London. Illustrated. 12mo. Cloth, $1.75

Digitized by Google

Smith. Wasting Diseases of Infants and Children.

By EUSTACE SMITH, M.D., F.R.C.P., Physician to the East London Hospital for Children, etc. Sixth Edition, Revised. Cloth, $2.00

Starling. Elements of Human Physiology.

By ERNEST H. STARLING, M.D. (Lond.), M.R.C.P., Joint Lecturer on Physiology at Guy's Hospital, London, etc. With 100 Illus. 12mo. 437 pages. Cloth, $1.00

Starr. The Digestive Organs in Childhood.

The Diseases of the Digestive Organs in Infancy and Childhood. With Chapters on the Investigation of Disease and the Management of Children. By LOUIS STARR, M.D., late Clinical Professor of Diseases of Children in the Hospital of the University of Pennsylvania; Physician to the Children's Hospital, Philadelphia. Second Edition. Illustrated. Octavo. Cloth, $2.00

The Hygiene of the Nursery.

Including the General Regimen and Feeding of Infants and Children, and the Domestic Management of the Ordinary Emergencies of Early Life, Massage, etc. Sixth Edition, Enlarged. 25 Illustrations. 12mo. Cloth, $1.00

*** General and specific rules for feeding are given, and Diet Lists from the first week up to the eighteenth month, with various recipes for artificial foods, peptonized milk, etc. Directions for the sterilization of milk, substitutes for milk, preparation of food for both well and sick children, nutritious enemata, etc., and the general management of the Nursery.

Stearns. Lectures on Mental Diseases.

By HENRY PUTNAM STEARNS, M.D., Physician-Superintendent at the Hartford Retreat; Lecturer on Mental Diseases in Yale University. With a Digest of Laws of the Various States Relating to Care of Insane. Illustrated. Cloth, $2.75; Sheep, $3.25

Stevenson and Murphy. A Treatise on Hygiene.

By Various Authors. Edited by THOMAS STEVENSON, M.D., F.R.C.P., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital, London, and SHIRLEY F. MURPHY, Medical Officer of Health to the County of London. In three octavo volumes.

Vol. I. With Plates and Wood Engravings. Octavo. Cloth, $6.00
Vol. II. With Plates and Wood Engravings. Octavo. Cloth, $6.00
Vol. III. Sanitary Law. Octavo. Cloth, $5.00

*** *Special Circular upon application.*

Stewart's Compend of Pharmacy.

Based upon "Remington's Text-Book of Pharmacy." By F. E. STEWART, M.D., PH.G., late Quiz-Master in Chemistry and Theoretical Pharmacy, Philadelphia College of Pharmacy; Lecturer on Pharmacology, Jefferson Medical College. Fifth Edition. Complete Tables of Metric and English Weights and Measures. *? Quiz-Compend ? Series.* Cloth, .80; Interleaved for the Addition of Notes, $1.25

Stirling. Outlines of Practical Physiology.

Including Chemical and Experimental Physiology, with Special Reference to Practical Medicine. By W. STIRLING, M.D., Sc.D., Professor of Physiology and Histology, Owens College, Victoria University, Manchester; Examiner in Physiology, Universities of Edinburgh and London. Third Edition. 289 Illustrations. Cloth, $2.00

Outlines of Practical Histology.

368 Illustrations. Second Edition, Revised and Enlarged. With new Illustrations. 12mo. Cloth, $2.00

Digitized by Google

Stöhr. Text-Book of Histology, Including the Microscopical Technic. 292 Illustrations.

By DR. PHILIPP STÖHR, Professor of Anatomy at University of Würzburg. Authorized Translation by EMMA L. BILLSTEIN, M.D., Demonstrator of Histology and Embryology, Woman's Medical College of Pennsylvania. Edited, with Additions, by DR. ALFRED SCHAPER, Demonstrator of Histology and Embryology, Harvard Medical School, Boston. Second American from the Seventh German Edition, Enlarged and Revised. 292 Illustrations. Octavo. Cloth, $3.00

Sturgis. The Students' Manual of Venereal Diseases.

By F. R. STURGIS, M.D., Sometime Clinical Professor of Venereal Diseases in the Medical Department of the University of the City of New York; formerly one of the Visiting Surgeons to Charity Hospital, Blackwells Island, Department of Venereal Diseases; Member of the American Association of Genito-Urinary Surgeons, etc. Seventh Edition, Revised and in part Rewritten by F. R. STURGIS, M.D., and FOLLEN CABOT, M.D., Instructor in Genito-Urinary and Venereal Diseases in the Cornell University Medical College; Genito-Urinary Out-Patient Surgeon to Bellevue Hospital; Visiting Dermatologist to the New York City (Charity) Hospital; Lecturer on Genito-Urinary and Venereal Diseases, University of Vermont, 1900. 12mo. *Nearly Ready.*

Sutton's Volumetric Analysis.

A Systematic Handbook for the Quantitative Estimation of Chemical Substances by Measure, Applied to Liquids, Solids, and Gases. Adapted to the Requirements of Pure Chemical Research, Pathological Chemistry, Pharmacy, Metallurgy, Photography, etc., and for the Valuation of Substances Used in Commerce, Agriculture, and the Arts. By FRANCIS SUTTON, F.C.S. Seventh Edition, Revised and Enlarged. With 112 Illustrations. 8vo. *In Press.*

Swain. Surgical Emergencies,

together with the Emergencies Attendant on Parturition and the Treatment of Poisoning. By WILLIAM PAUL SWAIN, F.R.C.S., Surgeon to the South Devon and East Cornwall Hospital, England. Fifth Edition. 149 Illustrations. 12mo. Cloth, $1.75

Swanzy. Diseases of the Eye and their Treatment.

A Handbook for Physicians and Students. By HENRY R. SWANZY, A.M., M.B., F.R.C.S.I., Surgeon to the National Eye and Ear Infirmary; Ophthalmic Surgeon to the Adelaide Hospital, Dublin. Sixth Edition, Thoroughly Revised and Enlarged. 158 Illustrations, one Plain Plate, and a Zephyr Test Card. 12mo. Cloth, $3.00

"Is without doubt the most satisfactory manual we have upon diseases of the eye. It occupies the middle ground between the students' manuals, which are too brief and concise, and the encyclopedic treatises, which are too extended and detailed to be of special use to the general practitioner."—*Chicago Medical Recorder.*

Symonds. Manual of Chemistry

for Medical Students. By BRANDRETH SYMONDS, A.M., M.D., Assistant Physician Roosevelt Hospital, Out-Patient Department, New York. Second Edition. 12mo. Cloth, $2.00

Taft. Index of Dental Periodical Literature.

By JONATHAN TAFT, D.D.S. 8vo. Cloth, $2.00

Talbot. Irregularities of the Teeth

and Their Treatment. By EUGENE S. TALBOT, M.D., Lecturer on Dental Pathology in Rush Medical College, Chicago. Second Edition, Revised. 234 Illustrations. Octavo. Cloth, $3.00

Digitized by Google

Tanner's Memoranda of Poisons

and their Antidotes and Tests. By THOS. HAWKES TANNER, M.D. Seventh Edition, Revised by JOHN J. REESE, M.D., late Professor of Medical Jurisprudence and Toxicology in the University of Pennsylvania. 12mo. Cloth, .75

Taylor. Practice of Medicine.

By FREDERICK TAYLOR, M.D., Physician to, and Lecturer on Medicine at, Guy's Hospital, London; Physician to Evelina Hospital for Sick Children. Fifth Edition. Cloth, $4.00

Taylor and Wells. Diseases of Children. Illustrated.

A Manual for Students and Physicians. By JOHN MADISON TAYLOR, A.B., M.D., Professor of Diseases of Children, Philadelphia Polyclinic; Assistant Physician to the Children's Hospital and to the Orthopedic Hospital; Consulting Physician to the Elwyn and the Vineland Training Schools for Feeble-minded Children; Neurologist to the Howard Hospital, etc.; and WILLIAM H. WELLS, M.D., Adjunct-Professor of Obstetrics and Diseases of Infancy in the Philadelphia Polyclinic; Instructor of Clinical Obstetrics, Jefferson Medical College. With 8 Plates and Numerous other Illustrations. 12mo. 743 pages. Cloth, $4.00

Temperature Charts

for Recording Temperature, Respiration, Pulse, Day of Disease, Date, Age, Sex, Occupation, Name, etc. Put up in pads; each .50

Tessier. Pneumotherapy and Inhalation Methods.

See COHEN, Physiologic Therapeutics, page 10.

Thorington. Retinoscopy

(The Shadow Test) in the Determination of Refraction at One Metre Distance with the Plane Mirror. By JAMES THORINGTON, A.M., M.D., Adjunct-Professor of Diseases of the Eye in the Philadelphia Polyclinic; Assistant Surgeon Wills Eye Hospital; Ophthalmologist to the Elwyn and Vineland Training Schools; Lecturer on the Anatomy, Physiology, and Care of the Eyes in the Philadelphia Manual Training Schools, etc. 38 Illustrations, several of which are Colored. Third Edition, Enlarged. 12mo. Cloth, $1.00

Refraction and How to Refract.

With 200 Illustrations, most of which are made from Original Drawings, and 13 of which are in Colors. 12mo. Cloth, $1.50

SYNOPSIS OF CONTENTS.—I. Optics. II. The Eye; The Standard Eye; Cardinal Points; Visual Angle; Minimum Visual Angle; Standard Acuteness of Vision; Size of Retinal Image Accommodation; Mechanism of Accommodation; Far and Near Point; Determination of Distant Vision and Near Point; Amplitude of Accommodation; Convergence; Angle Gamma; Angle Alpha. III. Ophthalmoscope; Direct and Indirect Method. IV. Emmetropia; Hyperopia; Myopia. V. Astigmatism or Curvature Ametropia; Tests for Astigmatism. VI. Retinoscopy. VII. Muscles. VIII. Cycloplegics; Cycloplegia; Asthenopia; Examination of the Eyes. IX. How to Refract. X. Applied Refraction. XI. Presbyopia; Aphakia; Anisometropia; Spectacles. XII. Lenses; Spectacle and Eye Glass Frames; How to Take Measurements for Them and How They Should be Fitted. Index.

Thorne. The Schott Methods of the Treatment of Chronic Diseases of the Heart.

With an Account of the Nauheim Baths and of the Therapeutic Exercises. By W. BEZLY THORNE, M.D., M.R.C.P. With Plates and Numerous other Illustrations. Third Edition, Revised and Enlarged. Octavo. Cloth, $1.75

Digitized by Google

Tomes' Dental Anatomy.

A Manual of Dental Anatomy, Human and Comparative. By C. S. TOMES, D.D.S. 263 Illustrations. Fifth Edition. 12mo. Cloth, $4.00

Dental Surgery.

A System of Dental Surgery. By JOHN TOMES, F.R.S. Fourth Edition, Thoroughly Revised by C. S. TOMES, D.D.S. With 289 Illustrations. 12mo. 717 pages. Cloth, $4.00

Treves. German-English Medical Dictionary.

By FREDERICK TREVES, F.R.C.S., assisted by DR. HUGO LANG, B.A. (Munich). 12mo. Half Russia, $3.25

Physical Education: Its Effects, Value, Methods, etc. 8vo.

Cloth, .75

Tuke. Dictionary of Psychological Medicine.

Giving the Definition, Etymology, and Synonyms of the Terms used in Medical Psychology, with the Symptoms, Pathology, and Treatment of the Recognized Forms of Mental Disorders, together with the Law of Lunacy in Great Britain and Ireland. Edited by D. HACK TUKE, M.D., LL.D., Examiner in Mental Physiology in the University of London. Two volumes. Octavo. Cloth, $10.00

"A comprehensive, standard book."—*The British Medical Journal.*

"It is vastly more than a Dictionary. It is an elaborate and complete Encyclopædia of Psychological Medicine; in fact, a small library in itself on that subject. The high expectations which Dr. Tuke's work in this field had raised are more than fulfilled. . . . It will be found to be a most useful reference handbook for the alienist and student. The general physician also cannot fail to find the book exceedingly useful in special cases."—*Boston Medical and Surgical Journal.*

"We believe that the student might obtain a better knowledge of insanity from this work than from most of the text-books, besides a great deal of interesting and valuable information nowhere else accessible."—*American Journal of Insanity.*

Traube. Physico-Chemical Methods.

By DR. J. TRAUBE, Privatdocent in the Technical High School of Berlin. Authorized Translation by W. D. HARDIN, Harrison Senior Fellow in Chemistry, University of Pennsylvania. With 97 Illustrations. 8vo. Cloth, $1.50

Thresh. Water and Water Supplies.

By JOHN C. THRESH, D.S.C. (Lond.), M.D., D.P.H. (Cambridge), Medical Officer of Health to the Essex County Council; Lecturer on Public Health, King's College, London; Fellow of the Institute of Chemistry; Member Society Public Analysts, etc. Second Edition, Revised. Illustrated. 438 pages. 12mo. Cloth, $2.00

Turnbull's Artificial Anesthesia.

A Manual of Anesthetic Agents in the Treatment of Diseases, also their Employment in Dental Surgery; Modes of Administration; Considering their Relative Risks; Tests of Purity; Treatment of Asphyxia; Spasms of the Glottis; Syncope, etc. By LAURENCE TURNBULL, M.D., PH.G., Aural Surgeon to Jefferson College Hospital, etc. Fourth Edition, Revised. 54 Illustrations. 12mo. Cloth, $2.50

Tuson. Veterinary Pharmacopœia.

Including the Outlines of Materia Medica and Therapeutics. By RICHARD V. TUSON, late Professor at the Royal Veterinary College. Fifth Edition, Edited by JAMES BAYNE, F.C.S., Professor of Chemistry and Toxicology at the Royal Veterinary College. 12mo. Cloth, $2.25

Digitized by Google

Tyson. The Practice of Medicine. Illustrated.

A Text-Book for Physicians and Students, with Special Reference to Diagnosis and Treatment. By JAMES TYSON, M.D., Professor of Medicine in the University of Pennsylvania; Physician to the University and to the Philadelphia Hospitals, etc. With Colored Plates and many other Illustrations. 8vo.

Cloth, $5.50; Leather, $6.50; Half Russia, $7.50

*** The large sale of this book has necessitated reprinting it several times. Dr. Tyson has taken advantage of these opportunities to revise and improve the work in many details.

"This work not only represents the work of a practitioner of great experience, but of a careful culling of the facts set forth in contemporary literature by one who well understands the art of separating the true from the false."—*The Journal of the American Medical Association, Chicago.*

"Represents the outcome of much well-directed labor, and constitutes a reliable and useful text-book."—*The London Lancet.*

"Few teachers in the country can claim a longer apprenticeship in the laboratory and at the bedside, none a more intimate acquaintance with students, since in one capacity or another he has been associated with the University of Pennsylvania and the Philadelphia Hospital for nearly thirty years. Moreover, he entered medicine through the portal of pathology, a decided advantage in the writer of a text-book. . . . The typography is decidedly above works of this class issued from our publishing houses. There is no American Practice of the same attractive appearance. The print is unusually sharp and clear, and the quality of the paper particularly good. . . . It is a piece of good, honest work, carefully conceived and conscientiously carried out."—*University Medical Magazine.*

***** Sample Pages and Illustrations sent free upon application.**

Guide to the Examination of Urine.

For the Use of Physicians and Students. With Colored Plate and Numerous Illustrations Engraved on Wood. Ninth Edition, Revised. 276 pages. 12mo. Cloth, $1.25

****A French translation of this book has been published in Paris.*

Handbook of Physical Diagnosis.

Third Edition, Revised and Enlarged. With Colored and other Illustrations. 278 pages. 12mo. Cloth, $1.50

Cell Doctrine.

Its History and Present State. Second Edition. Cloth, $1.50

United States Pharmacopœia. 1890.

Seventh Decennial Revision. Cloth, $2.50 (Postpaid, $2.77); Sheep, $3.00 (Postpaid, $3.27); Interleaved, $4.00 (Postpaid, $4.50). Printed on one side of page only, unbound, $3.50 (Postpaid, $3.90).

Select Tables from the U. S. P. (1890).

Being Nine of the Most Important and Useful Tables, printed on Separate Sheets. Carefully put up in Patent Envelope, .25

Ulzer and Fraenkel. Introduction to Chemical-Technical Analysis.

By PROF. F. ULZER and DR. A. FRAENKEL, Directors of the Testing Laboratory of the Royal Technological Museum, Vienna. Authorized Translation by HERMANN FLECK, NAT.SC.D., Instructor in Chemistry and Chemical Technical Analysis in the John Harrison Laboratory of Chemistry, University of Pennsylvania, with an Appendix by the Translator relating to Food Stuffs, Asphaltum, and Paint. 12 Illustrations. 8vo. Cloth, $1.25

Van Nüys on the Urine.

Chemical Analysis of Healthy and Diseased Urine, Qualitative and Quantitative. By T. C. VAN NÜYS. 39 Illustrations. Octavo. Cloth, $1.00

Digitized by Google

Van Harlingen on Skin Diseases.

A Practical Manual of Diagnosis and Treatment, with Special Reference to Differential Diagnosis. By ARTHUR VAN HARLINGEN, M.D., Emeritus Professor of Diseases of the Skin in the Philadelphia Polyclinic; Dermatologist to the Children's Hospital. Third Edition, Revised and Enlarged. With Formulæ and Illustrations, several being in Colors. 580 pages. Cloth, $2.75

"As would naturally be expected from the author, his views are sound, his information extensive, and in matters of practical detail the hand of the experienced physician is everywhere visible."—*The Medical News.*

Virchow's Post-mortem Examinations.

A Description and Explanation of the Method of Performing them in the Dead-House of the Berlin Charité Hospital, with Especial Reference to Medico-Legal Practice. By PROFESSOR VIRCHOW. Translated by DR. T. P. SMITH. Illustrated. Third Edition. Cloth, .75

Voswinkel. Surgical Nursing.

A Manual for Nurses. By BERTHA M. VOSWINKEL, Graduate Episcopal Hospital, Philadelphia; late Nurse-in-Charge Children's Hospital, Columbus, O. Second Edition, Revised and Enlarged. 111 Illustrations. 12mo. Cloth, $1.00

Walker. Students' Aid in Ophthalmology.

By GERTRUDE A. WALKER, A.B., M.D., Clinical Instructor in Diseases of the Eye at Woman's Medical College of Pennsylvania. 40 Illustrations and Colored Plate. 12mo. Cloth, $1.50

Walsham. Surgery: Its Theory and Practice.

For Students and Physicians. By WM. J. WALSHAM, M.D., F.R.C.S., Senior Assistant Surgeon to, and Demonstrator of Practical Surgery in, St. Bartholomew's Hospital; Surgeon to Metropolitan Free Hospital, London. Sixth Edition, Revised and Enlarged. With 410 Engravings. Cloth, $3.00

Ward. Notes on Massage.

Including Elementary Anatomy and Physiology. By JESSIE M. WARD, Instructor in Massage in the Pennsylvania, Philadelphia, Jefferson, and Woman's Hospitals, etc. 12mo. Interleaved. Paper Cover, $1.00

Warren. Compend of Dental Pathology and Dental Medicine.

Containing all the most Noteworthy Points of Interest to the Dental Student and a Chapter on Emergencies. By GEORGE W. WARREN, D.D.S., Professor of Clinical Dentistry and Oral Surgery; Clinical Chief, Pennsylvania College of Dental Surgery, Philadelphia. Third Edition, Enlarged. Illustrated. *Being No. 13 ? Quiz-Compend ? Series.* 12mo. Cloth, .80; Interleaved for the Addition of Notes, $1.25

Dental Prosthesis and Metallurgy.

129 Illustrations. Cloth, $1.25

Weber and Hinsdale. Climatology—Health Resorts—Mineral Springs.

See COHEN, Physiologic Therapeutics, page 10.

Wells. Compend of Gynecology.

By WM. H. WELLS, M.D., Instructor of Obstetrics, Jefferson Medical College, Philadelphia; Fellow of the College of Physicians of Philadelphia. Second Edition, Revised. 140 Illustrations. *Being No. 7 ? Quiz-Compend ? Series.* 12mo. Cloth, .80; Interleaved for Notes, $1.25

Digitized by Google

Westland. The Wife and Mother.

A Handbook for Mothers. By A. WESTLAND, M.D., late Resident Physician, Aberdeen Royal Infirmary. Cloth, $1.50

Wethered. Medical Microscopy.

A Guide to the Use of the Microscope in Practical Medicine. By FRANK J. WETHERED, M.D., M.R.C.P., Demonstrator of Practical Medicine, Middlesex Hospital Medical School; Assistant Physician, late Pathologist, City of London Hospital for Diseases of the Chest, etc. With a Colored Plate and 101 Illustrations. 406 pages. 12mo. Cloth, $2.00

Weyl. Sanitary Relations of the Coal-Tar Colors.

By THEODORE WEYL. Authorized Translation by HENRY LEFFMANN, M.D., PH.D. 12mo. Cloth, $1.25

Whitacre. Laboratory Text-Book of Pathology.

By HORACE J. WHITACRE, M.D., Demonstrator of Pathology, Medical College of Ohio, Cincinnati. Illustrated with 121 Original Drawings and Microphotographs. 8vo. Cloth, $1.50

White. The Mouth and Teeth. Illustrated.

By J. W. WHITE, M.D., D.D.S. Cloth, .40

White and Wilcox. Materia Medica, Pharmacy, Pharmacology, and Therapeutics. Fourth Edition.

A Handbook for Students. By W. HALE WHITE, M.D., F.R.C.P., etc., Physician to, and Lecturer on Materia Medica and Therapeutics, Guy's Hospital; Examiner in Materia Medica to the Conjoint Board, etc. Fourth American Edition, Revised by REYNOLD W. WILCOX, M.A., M.D., LL.D., Professor of Clinical Medicine and Therapeutics at the New York Post-Graduate Medical School and Hospital; Visiting Physician, St. Mark's Hospital; Assistant Visiting Physician, Bellevue Hospital. Fourth Edition, Thoroughly Revised. 12mo. Cloth, $3.00; Leather, $3.50

Williams. Manual of Bacteriology.

By HERBERT U. WILLIAMS, M.D., Professor of Pathology and Bacteriology, Medical Department, University of Buffalo. 78 Illustrations. 12mo. Cloth, $1.50

Wilson. Handbook of Hygiene and Sanitary Science.

By GEORGE WILSON, M.A., M.D., F.R.S.E., Medical Officer of Health for Mid-Warwickshire, England. With Illustrations. Eighth Edition. 12mo. Cloth, $3.00

Wilson. The Summer and its Diseases.

By JAMES C. WILSON, M.D., Professor of the Practice of Medicine and Clinical Medicine, Jefferson Medical College, Philadelphia. Cloth, .40

Wilson. System of Human Anatomy.

Eleventh Revised Edition, Edited by HENRY EDWARD CLARK, M.D., M.R.C.S. 492 Illustrations, 26 Colored Plates, and a Glossary of Terms. 12mo. Cloth, $5.00

Winckel. Text-Book of Obstetrics.

Including the Pathology and Therapeutics of the Puerperal State. By DR. F. WINCKEL, Professor of Gynecology, Royal University Clinic for Women in Munich. Authorized Translation by J. CLIFTON EDGAR, A.M., M.D., Professor of Obstetrics and Clinical Midwifery, Cornell University Medical Department, New York. 190 Illustrations. Octavo. Cloth, $5.00; Leather, $6.00

Digitized by Google

Windle. Surface Anatomy and Landmarks.

By B. C. A. WINDLE, D.Sc., M.D., Professor of Anatomy in Mason College, Birmingham, etc. Second Edition, Revised by T. MANNERS SMITH, M.R.C.S. Colored and other Illustrations. 12mo. Cloth, $1.00

Winternitz. Hydrotherapy—Thermotherapy—Balneology.

See COHEN, Physiologic Therapeutics, page 10.

Woakes. Deafness, Giddiness, and Noises in the Head.

By EDWARD WOAKES, M.D., Senior Aural Surgeon, London Hospital; Assisted by CLAUD WOAKES, M.R.C.S., Assistant Surgeon to the London Throat Hospital. Fourth Edition. Illustrated. 12mo. Cloth, $2.00

Wood. Brain Work and Overwork.

By H. C. WOOD, Clinical Professor of Nervous Diseases, University of Pennsylvania. 12mo. Cloth, .40

Woody. Essentials of Chemistry and Medical Urinalysis.

By SAMUEL E. WOODY, A.M., M.D., Professor of Chemistry and Diseases of Children in the Medical Department, Kentucky University. Fourth Edition, Revised and Enlarged. Illustrated. 12mo. Cloth, $1.50

"The fact that Prof. Woody's little book has reached a third edition in such a short time is sufficient proof of its usefulness for, and demand by, the medical student. The selection of the material and its plan of presentation, resulting from the author's large experience as a practitioner and teacher of medical chemistry, is well intended to offer to the student that which is really essential for his limited college course, and, it is to be hoped, a basis for further instruction in the important branch of medical science."—*The American Journal of Medical Sciences, Philadelphia.*

ONE HUNDRED THOUSAND COPIES OF

GOULD'S MEDICAL DICTIONARIES have been sold since March, 1890, when the first edition of the first book was published. Only good books could have had such a phenomenal sale. They are practical, concise, useful, well printed, strongly bound, but what is more to the point, they are up-to-date and are kept up-to-date. They contain thousands of words not in other dictionaries, and include groups of facts in the form of tables that render them extremely valuable. What the AMERICAN JOURNAL OF MEDICAL SCIENCES said of the Student's Dictionary applies to all: "One pleasing feature of the book is that the reader can almost invariably find the definition under the word he looks for, without being referred from one place to another, as is too commonly the case in medical dictionaries." See page 15 of this Catalogue, and write for special circular showing sample pages, illustrations, and descriptions. ✱ ✱ ✱

Digitized by Google

Digitized by Google

Digitized by Google

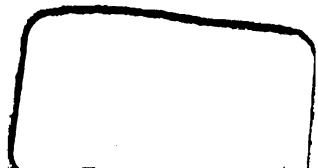
This book should be returned to the Library on or before the last date stamped below.

A fine of five cents a day is incurred by retaining it beyond the specified time.

Please return promptly.

DEC 9 1918

FEB 26 1924



Digitized by Google

3 2044 081 576 456

Digitized by Google